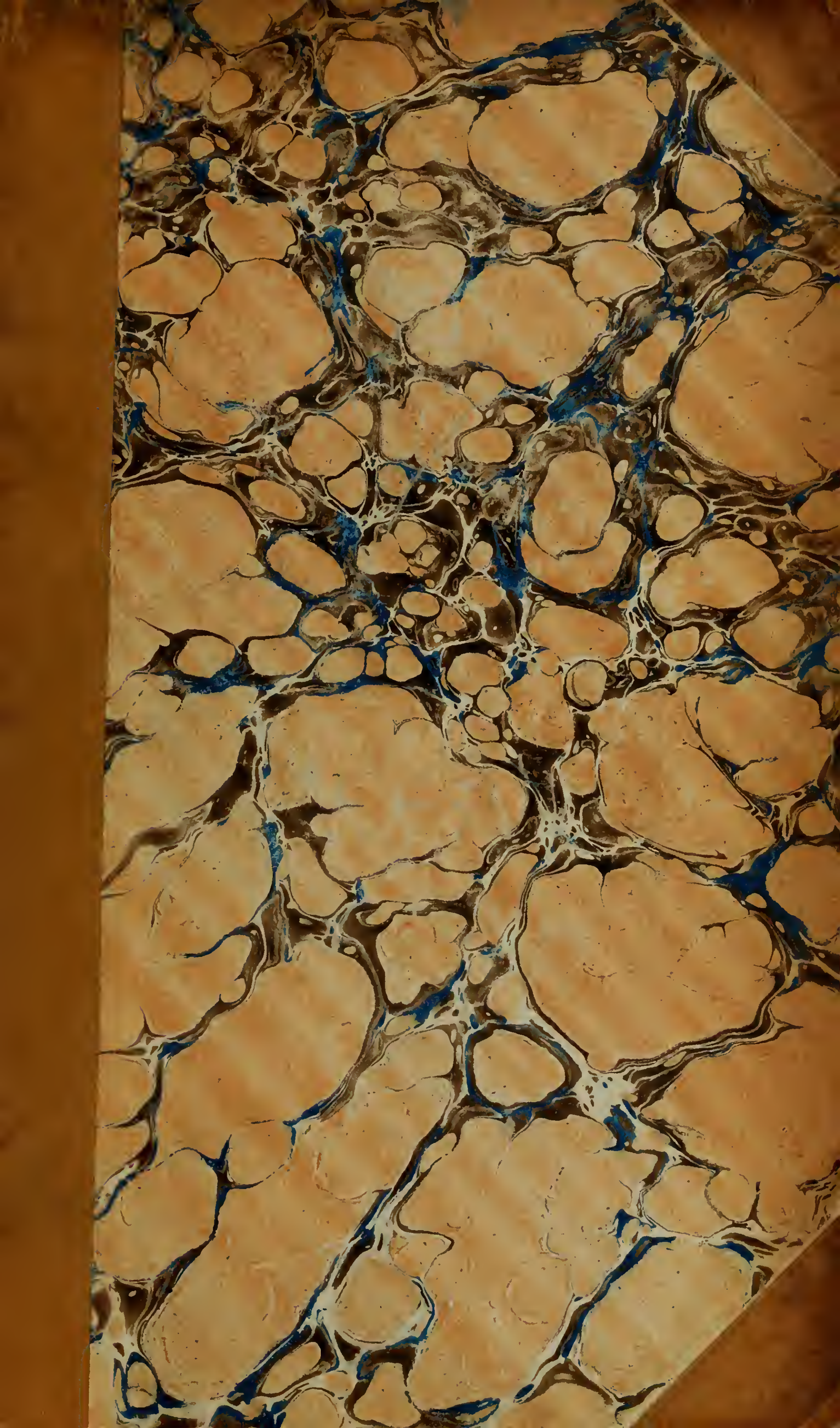

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EDITORIAL.

ITEMS AND NOVELTIES.

On Deep Sea Sounding.—Sir William Thomson has lately communicated to the British Society of Telegraphic Engineers, a paper upon his new method of deep sea sounding by means of piano-forte wire. We condense the following description of it from the *Telegraphic Journal:*

Wire is better than rope for this purpose, because of the smallness of its area and the smoothness of its surface. The size employed is No. 22 of the Birmingham wire gauge, weighing 14½ pounds to the nautical mile, and bearing a weight of 230 to 240 pounds before breaking. Messrs. Johnson of Manchester made for him a piece of this wire three miles long, drawn from a single ingot of crucible steel, and capable, by actual test, of sustaining the above weight. The importance of having the sounding wire in one piece is very great, since splicing is almost an impossibility. At first the two ends of the wire were twisted together and solder was run between them; yet on testing the joint, the wire itself broke close to it, at a strain from 10 to 20 pounds less than, under other conditions, the wire sustained. The sudden change in area is an element of weakness; and to avoid it, an exceedingly gradual commencement of the pressure must be secured. This is effected by a splice at least two feet long. The two wires are placed parallel for this distance, seized in the middle, and the two ends successively turned round the contiguous straight portion of wire. If the wires be previously coated with marine glue, to increase the surface friction, and the ends be kept down by a serving of twine, the splice is capable of sustaining as great a load as the wire itself. The next difficulty to be overcome was in the apparatus for hauling in the wire. Originally a wheel or whim a fathom in circumference, was used, the first sounding made with it being one of 2700 fathoms in the Bay of Biscay. After hauling in 1500 fathoms, the wheel labored and the last 800 fathoms were recovered with great difficulty. The first remedy applied was to stop the process after say 20 fathoms, to take the strain off the wire, and to ease it round the wheel; but, beside being very tedious, it did not give accurate results. In the American Navy, the weight is automatically detached upon striking the bottom and then the wire is easily pulled in. But as it was very undesirable to lose 30 or 35 pounds of lead or iron at every sounding, the author contrived an apparatus by which the weight could always be recovered; at least from depths not exceeding 3000 fathoms. When a sounding is made from a ship hove to for the purpose, a serious difficulty is encountered in the tendency of the wire to kink. This is obviated by fastening the weight to the ring or clamp at the end of the wire, by means of 15 fathoms of cod line, the clamp itself weighing about 4 pounds. When the weight strikes the bottom, the paying out of the wire ceases before the clamp strikes; hence there is no wire coiled on the bottom and there is no kinking. In order to arrest the paying out of the sounding wire at the proper time, a measured resistance is applied systematically to the wheel, which resistance is always to be more than enough to balance the weight of the wire out. For example, let this resistance exceed by 10 pounds the weight of the wire paid out. The sinker weighs 30 and the clamp 4 pounds. Hence 24 pounds represents the moving force; a force sufficient to reach the bottom at 3000 fathoms, in three quarters of an hour. By means of a time-counter, narrowly watched by the person in charge, three pounds is added to the brake for every 250 fathoms of wire paid out; this is 12 pounds for every thousand fathoms, which is about the weight in water of this length of wire. Now when the weight strikes the bottom, instead of there being a downward strain on the wire of 24 pounds, there is a resistance to its motion of ten pounds. A few turns of the wheel—two or three at the most—and the motion is stopped; and, long before the clamp gets to the bottom, there being 10 fathoms of line between it and the sinker, the wheel stops. The wire-wheel is then run back, a spun-yarn stopper is put on the wire, the strain is taken off, and the wire is carried over the top of the large wheel, one coil being enough for 3000 and 2 for 4000 fathoms. A pulley with a sharp V groove is put on each side; and then with a snatch-block, and with a deck ten fathoms inboard, three men hauling on each side can haul up at the rate of 8 nautical miles an hour. Moreover, by a suitable arrangement, the excess of stress caused by a heavy sea, may be regulated to the force exerted in hauling in.

In relation to the adoption of this method of sounding in the British Navy, Sir. Wm. Thomson goes on to say: "I think it highly desirable that this process should be taken up by our own admiralty. There is a great tendency to the other side. I have a semi-official letter to the effect: 'When you have your apparatus perfected, we may be ready to try it.' I may say that it seems a little strange that, after my having intimated, in the month of June, 1871, the perfect success of wire for sounding in depths of 2700 fathoms, the Challenger was allowed to go to sea without taking advantage of this process, and that a year and a half later, I should be told: 'When you have perfected your instrument we will give it a trial.' The American Navy looked upon the matter with different eyes and certainly in a different spirit. They moved those who had the direction and they took it up with the very greatest zeal. They found my apparatus full of defects, but they never asked me to perfect it, but they perfected it in their own way and they obtained results. I went on independently in another line and made a considerably different apparatus from that which is now being used by the Americans; but I certainly was very much struck by the great zeal and the great ability which the American naval officers showed in taking up a thing of this description which had once been proved to be good, and charging themselves with improving the details and making it a workable process."

The paper closes with an account of the method of making flying soundings with wire. During the Hooper telegraph expedition from Pernambuco to Para, soundings were taken every two hours without stopping the ship. A 30 pound weight was hung by two fathoms of cord (though five would have been better) to the clamp, and the wheel was let go with a resistance of about 8 pounds. When the ship was moving $4\frac{1}{2}$ knots, the cable was paying out at 6 knots; and after 150 to 175 fathoms had run out, the wheel would suddenly almost cease to turn, and was then stopped. In this way flying soundings were made in water 150 fathoms deep, the ship going 6 knots per hour. The wire is protected from rust either by immersion in oil, after the American plan, or in caustic soda, as on board the Hooper.

The Sczaroch, a new Russian projectile.—A new shell, under the above name, has just been adopted for the Russian artillery, which seems to have certain advantages. When the old spherical shell was replaced by the elongated shell, now entirely in use, the argument was the necessity of obtaining a higher initial velocity, which was possible only with rifled guns. There was not an artilleryman who did not regret the sacrifice thus made of the ricochet shot; a shot extremely useful in certain cases, and apparently quite impossible with an elongated projectile. Some two years ago a Russian officer devised a shell which was a time or a percussion shell and at the same time could give the results of a ricochet shot. The sczaroch, as it is called, is an elongated shell, the head of which is completely spherical; a round shell upon the end of an iron cylinder. The two parts are united together by a comparatively slight thickness of metal. When fired, the sczaroch leaves the gun like an ordinary shell; but when it bursts, the cylindrical part alone flies in pieces, while the spherical head continues its flight intact and may ricochet for hundreds of yards further. The advantage of such a shell against artillery, for example, is very great. After bursting and scattering its fragments among the guns of the enemy, the head goes on to plunge into the infantry still further back. It is only to be used in Russia however, for cannon of moderate size.

On the Action of Spiegeleisen in the Bessemer Process.—An investigation into the function performed by the spiegeleisen when added to the Bessemer charge has been made by Bender. A portion of the metal, when ready for the charge of spiegeleisen, was run into a white hot clay mould and slowly cooled. Its structure was coarsely crystalline, a condition favored by the oxygen contained in it. It was brittle under the rolls, but tough and hard under the chisel. Upon analysis, it contained 0·35 per cent. of oxygen. The action of the spiegeleisen upon the iron, the author then calculates as follows: The charge of 3,500 kilograms lost ten per cent. of slag, leaving 3,150 kilograms of metal, which at the above percentage, would contain 11·02 kilograms of oxygen. To this, 325 kilograms of spiegeleisen was added, containing five per cent. of carbon and eight per cent. of manganese; i. e., 16·25 kilograms of carbon and 26 kilograms of manganese. Since 55 parts of manganese takes up 16 of oxygen 26 kilograms requires 7·67 kilograms; leaving 3·45 kilograms of oxygen. Moreover, as the carbon is also active, as the flame shows, the 3·45 kilograms of oxygen would require 2·58 kilograms of carbon, which, subtracted from the 16·25 kilograms contained in the spiegeleisen, leaves 13·67 kilograms of carbon. Before adding this, the Bessemer metal contained 0·08 per cent. of carbon, equal to 2·52 kilograms; hence it contained afterward 16·2 kilograms. Upon analysis, the steel obtained contained only from 0·15 to 0·20 per cent of manganese; hence the author believes that since both the manganese and the carbon added in the spiegeleisen, operate upon the oxygen, the excess of manganese and its equivalent of carbon pass away in the slag, leaving only the above quantity—0·15 to 0·20 per cent—combined in the steel. As 0·15 per cent. equals 5·17 kilograms of manganese, equivalent to 1·12 kilograms of carbon, the carbon left would be (16·2–1·12) 15 kilograms to about 3,450 kilograms of metal, or 0·43 per cent. Actual experimental determination gave 0·40 per cent. carbon.

It appears, therefore, that from three-fourths to four-fifths of the manganese introduced by the spiegeleisen, is lost in the slag; whether the small portion which the steel retains is of any advantage to it or not, is yet undecided. Moreover, the silicon is slightly increased, and the sulphur slightly diminished by the addition of the spiegeleisen. The author maintains that the spiegeleisen may be replaced with advantage, both as to quality and quantity of the product, by a good white carburetted iron. The great difficulty with both, however, lies in the fact that the carbonic oxide formed by the carbon which they contain, in acting on the oxygen of the Bessemer metal, appears to be dissolved in the liquid metal and to be evolved on solidification. This "blowing" as it is termed, is a serious injury to the metal. The author hence thinks it desirable to replace the carbon by a substance which forms when united with oxygen an easy fusible slag instead of a gaseous product.

On the Temperature obtained in Freezing Mixtures.—One of the results obtained by Berthelot in his admirable researches in thermo-chemistry—and by no means one of the least important, we may add—is the determination of the law according to which refrigerating mixtures act, thus rendering it possible to ascertain by a very simple calculation exactly what temperature can be obtained. If, for example, sulphuric acid of specific gravity 1·78, crystallized, be mixed with snow or pounded ice, three thermic effects are produced; first the acid liquefies, absorbing heat; second, the ice melts, also absorbing heat; and third, the two liquids unite, evolving heat. The actual figures are as follows, three parts (58 grams) of acid and eight parts (153 grams) of ice, both at 0°, being mixed:

Melting of the crystallized acid	— 1840 calories	—9015
“ “ “ ice	--12155	
Union of acid and water	+ 4900	

211 grams of the mixture absorb then 9015 calories of heat. If now this number be divided by the product of the weight, 211 grams, and the specific heat of the mixture, 0·813, which is 171·5, the quotient is — 52·6°, the final temperature obtained. If the substances be cooled to — 20° before mixture, the final temperature is — 62°. In the last century, mercury was frozen by a mixture of liquid sulphuric acid and snow. Theory shows that when one part of sulphuric acid containing one-fifth water, is mixed with three parts of snow, both cooled to — 7°, the final temperature is — 51°. So calculation and experiment agree that when nitric acid is mixed with twice its weight of snow the temperature is lowered to — 56°. Of the three ways of producing cold: (1) by converting a solid or a liquid into a gas, (2) by liquefying a solid either by contact with a liquid or another solid, or (3) by chemical action in solution, producing a substance which absorbs more heat than the bodies originally present—the first is immensely the most effective. Theory shows that the evaporation of ether should produce a cold of —192°; of carbon disulphide, — 530°; of liquefied ammonia — 460°; of hyponitrous oxide (liquid) — 440°. Were it not for the fact that the tension of the vapor evolved from these liquids soon becomes so feeble that the cold produced by evaporation is balanced by absorption from surrounding bodies, a fact which prevents the production of a temperature more than 100° below the boiling point of the liquid, it would undoubtedly be possible practically to attain in this way very low temperatures, perhaps even the absolute zero, generally fixed at — 273°.

Postal Cards in the Different Countries of Europe.—The idea of postal cards is attributed to Dr. Emanuel Hermann, professor in the Vienna Military Academy. They were introduced into England in 1870, at the price of one half-penny, (one cent), the letter postage being one penny. The average circulation there of these postal cards has risen to a million and a half a week. More than seventy-five millions were sent in 1871, and this number was exceeded in 1872. The number of letters mailed, so far from diminishing in consequence of the introduction of the cheaper postal card, as had been predicted, has actually increased; in place of 863 millions of letters carried in 1870, 915 millions were transported in 1871, an increase of 52 millions. This enormous increase raises the mean percentage of the annual progression, which, for the five previous years, from 1866 to 1870, had been four per cent, up to six per cent.

In Germany, the introduction of card-correspondence was decreed in June, 1870, and it began practically a month later. The advantages offered by it caused it to be rapidly extended, although the price had been fixed at that time at one groschen (2½ cents), the same as letter postage. On the first of July, 1872, this price was reduced to one half a groschen (1¼ cents), letter postage remaining as before. Here also the introduction of the postal card has not interfered with the number of letters mailed, which, in place of 205 millions in 1870, became 240 millions in 1871. A most valuable addition to the postal card system, moreover, has been adopted in Germany, and has extended to Holland, to Belgium and to Switzerland. Beside the simple postal card, a double one is also issued, having a pre-paid card attached for the answer. The two cards correspond in size, each bears the stamp and they are sold at a double price.

In Switzerland, the postal card system was introduced October 1st, 1870, the price being five centimes (one cent). In 1871, 1, 713,710 cards were sent. The letters mailed increased from 20,477,844 in 1870 to 22,563,351 in 1871.

Belgium adopted postal cards July 1st, 1871, the price being five centimes (one cent). At first the system was local, but it has since become general. The number of letters sent, has, as in other countries, steadily increased. On the first of January, 1873, the Minister of Public Works, under whose direction are all postal and telegraphic arrangements, ordered the issue of double postal cards having a prepaid card for the answer.

Norway has had postal card correspondence since January 1st, 1872, the price at first being that of ordinary letter-postage, 9 skillings (2·9 cts). It has since been reduced to 2 skillings within the same postal district. The results generally are regarded as satisfactory.

In Sweden, the price of the postal-card at first fixed at 12 ore (3½ cts), has been reduced to 10 ore (2·8 cts). In Denmark, the system was adopted April 1st, 1871. The general card costs 4 schillings (2·4 cts) and the district card 2 schillings (1·2 cts).

In Russia, postal cards were introduced January 1st, 1872. The general card is furnished at 5 kopecks (4 cts) and the district card at 3 kopecks (2·4 cts.) In Austria, the postal card costs 2 kreutzers (one cent.) The system was adopted in October, 1869, and the first year eight millions of cards were sold.

Spain has decided upon postal cards; Greece and Portugal are about to issue them; and in Italy the same course has been resolved upon. Turkey alone has failed to see the advantages of the postal system and to adopt it.

On a New and Constant Thermo-Electric Generator.— The direct production of electricity from heat, and its utilization in practice as a source of power, has not, until now, been a commercial success. Unquestionably the best thermo-electric combination thus far obtained is that of Mr. Farmer, of Boston, in which an alloy of zinc and antimony constitutes the positive, and German silver or copper the negative plate. Such an electro-motor was exhibited at the Paris Exposition of 1867, and excited great interest. The difficulty, however, in their use on the large scale lies in the fact that when in action they lose their activity rapidly and "run down." Clamond has lately investigated the reason of this, and he finds it to be due to two causes: first, to the oxidation of the surfaces of contact of the two bars under the influence of the heat; and, second, to the cracking of the crystalline bar and its breaking into transverse sections. While, therefore, the electro-motive force of the apparatus undergoes no diminution, the internal resistance is so increased as to render the combination useless after a little time. The first of these difficulties Clamond has overcome by making some oblique cuts in the end of the flexible plate, and bending the intermediate tongues alternately to either side. When the melted metal is poured round this plate it flows into the spaces thus enclosed, and makes a more perfect contact. The second cause of deterioration was not so easily overcome. Annealing was found to be of no use, and it was finally ascertained that to render the bars homogeneous, crystallization must be prevented. This was effected by heating the moulds in which the zinc-antimony bars were cast, to a temperature near that at which the alloy fuses, and by pouring in the metal at a temperature near its solidifying point. In this way, using the zinc-antimony alloy in connection with strips of iron, the author has succeeded in constructing a thermo-electric generator, which remained in action in the laboratory of M. Jamin, at the Sorbonne, for six entire months without deterioration. This apparatus consisted of three rings, each composed of ten pairs of bars, arranged radially. In the interior cylindrical space was placed an earthenware tube full of holes, serving as a gas-burner. The entire apparatus weighed about 14 pounds, and at an expense per hour, of six cubic feet of gas, costing in Paris one cent, it deposited two-thirds of a troy ounce of copper; being equivalent to a Bunsen cell seven inches high.

Duchemin's Circular Compass.—A new compass has been invented in France by M. Duchemin, the magnetic force of which resides, not in a bar or needle, as in the ordinary instrument, but in a flat steel ring, magnetized, with its poles at two opposite extremities of the same diameter. This ring, supported upon an aluminum traverse, pivoted on agate at its centre, has attached to it the ordinary compass card, and acts promptly and efficiently. The author claims for it the following advantages: (1) a magnetic power, double that of a needle whose length is that of the diameter of the ring; (2) two neutral points instead of one, as in the needle; whence it happens that none of the magnetism escapes, and that strong sparks like those from the Holtz machine do not derange the poles; (3) a better and more prompt performance of the compass, the card seeming to float, as it were, in a liquid; (4) a large increase in the sensitiveness of the instrument; (5) the ability to regulate the magnetic intensity of the ring, and thus to compensate for local causes. This is effected by means of a second magnetized steel ring, smaller than, and inside of, the first, the position of which—and therefore its neutralizing action—may be easily adjusted. Under the direction of the Minister of the Marine, a trial trip of the new compass was made on the steamboat Faon with very satisfactory results. M. Duchemin now proposes, as an improvement, the use of a set of such rings, forming a spherical or spheroidal system of still greater magnetic power.

The Pernot Rotary Puddling Furnace.—A new puddling apparatus, designed and constructed by M. Pernot, has been brought to the notice of the Society of Civil Engineers of France. In this furnace, charges of 18 cwt. of fine iron obtained from charcoal pig, or 22 cwt. of ordinary iron made from common pig, are obtained at each operation. The production varies according to the nature of the pig employed, ranging from double to treble the quantity obtained in an ordinary puddling furnace. With pig iron from Pouzin we have made 4½ tons per run, which operation lasts about two hours. One ton of this pig gives nearly 19 cwt. of bars. It is a curious sight to see seventeen or eighteen balls drawn successively from the same furnace, the last ball being as hot and as free from cracks as the first one, and remarkably clean in appearance. The cost of production, compared with that of ordinary furnaces, is in favor of the new system. The process of M. Pernot is now a practical one, and carried on with the certainty of obtaining the different products expected from a puddling furnace, such as fine iron from charcoal pig, ordinary iron, and puddled steel. In the old furnace it is always the same layer of iron which is subject to the action of the scoriæ, and the parts touching the bed and bottom do not come within the influence of this action. In the rotary furnace, with inclined bed or bottom, the different particles come successively in thin sheets just as they are dragged along by the rotary motion to the upper region of the furnace, and there they are not submitted too long to the oxidizing action, because immediately after they dip down again into the bath in the lower part of the furnace. The same reasons produced very complete heating of the whole mass of metal. M. Pernot has furnaces with rotary bed or bottom for the fusion of steel, by adding to it the superheating obtained by means of gas generators and Siemens regenerators. To say that he has succeeded would not be wholly correct. This process, from the peculiar mode of loading, and from the action of rotation which gives a better heating and more rapid decarburation, has so much improved the condition in which cast steel can be obtained that there is no longer any analogy with the old methods. The same gas producers which were used for a Siemens-Martin furnace are now applied to this new furnace, giving twice as much steel in the same time as before, and with a corresponding economy in the working expenses. —*Iron Age.*

Bibliographical Notices.

TRI-NITRO-GLYCERIN, AS APPLIED IN THE HOOSAC TUNNEL, etc. By GEORGE M. MOWBRAY, Operative Chemist. *With thirteen* *illustrations, tables, and appendix. Third Edition, re-written, 8vo. pp.* 124. *New York,* 1874. *D. Van Nostrand.* Mr. Mowbray stands confessedly at the head of nitro-glycerin manufacturers in this country. Thoroughly trained in early life as a manufacturing chemist, he has so successfully applied his knowledge that the manufacture and use of this terrible explosive agent have been rendered almost absolutely safe. In proof of this assertion is the fact that, during the past six years, he has produced, at the Hoosac Tunnel alone upwards of five hundred thousand pounds of nitro-glycerin; and this with only two accidents, both of them attributable to the grossest carelessness on the part of workmen. We are glad therefore to have a monograph from his facile pen upon this most efficient explosive, so essential, now-a-days, to all enterprises requiring the excavation of rock. Mr. Mowbray's operations on the large scale, were commenced at North Adams, in the winter of 1867–8, under a contract with the Massachusetts Tunnel Commission. They have continued uninterruptedly up to the present time, and have been carried forward with an energy, an ability, and a persistency which renders their great success no secret. In the book before us—which has already reached its third edition—he has given us an admirable statement of facts. The opening chapter is devoted to a sketch of the difficulties attending the first introduction of nitro-glycerin in practice, by reason of the fearful explosions in New York, Panama, and San Franscisco, of the impure product of Nobel. The author then discusses the relative value of gun cotton and of nitro-glycerin; states the results of the experiments already made with the latter at the Hoosac Tunnel, in Erie Harbor, at Dimon's reef and Hallet's Point, N. Y., and in the oil wells of western Pennsylvania; describes the various processes for the manufacture and the analysis of nitro-glycerin, and of the various mixtures of this substance with absorbents, which have been proposed as substitutes; gives an account of the entire method of working with nitro-glycerin at the Hoosac Tunnel; corrects some errors concerning this substance, to be found in current literature; treats of the various electric and magnetic machines by which the explosion may be effected, and of the various fuses which may be employed for the purpose; and closes with some succinct and excellent instructions for handling and using the nitro-glycerin. One cannot read these interesting pages without being impressed, not only with the great value, not to say the absolute necessity of, nitro-glycerin in all tunnelling operations, but also with the indefatigable labors which have rendered its use on this immense scale, possible. It is to Mr. Mowbray, beyond question, that we owe the determination of the conditions of its safety. Recognizing at once, the important chemical fact that the most efficient, as well as the safest, nitro-glycerin, required the use of the strongest acids (acids, too, which, not being found in commerce had to be made upon the premises) he devised a most ingenious process for using these acids with economy and safety by blowing a stream of cold air through them while the glycerin enters. Thus originated his tri-nitro-glycerin, by far the safest, as it is the purest and the strongest, which is now in commerce. Moreover, the care employed in having the glycerin pure and dry, and in having the acid mixture thoroughly cooled when the glycerin is run into it, contributes essentially to the result. His product is therefore a colorless oily liquid, of specific gravity 1·6 at 60° F. It is insoluble in water, soluble in alcohol and ether, has no odor, but has an aromatic taste, though the minutest quantity on the tongue causes, in a few minutes, a severe but transient headache. Unlike other nitro-glycerins, the products of its explosion are neither offensive nor deleterious in their action upon the workmen. Another important point, however, is here to be noted. After production, the nitro-glycerin is placed in earthenware jars holding sixty pounds and kept at the temperature of 70° F. for seventy-two hours, to fine. It is then run into square tin cans holding 56 pounds, for packing. Now, it was by a fortunate accident that Mr. Mowbray learned the secret of subsequent safety, and ascertained that nitro-glycerin is inexplosible when solid. Next to its purity therefore, nitro-glycerin owes its safety during transportation to its being previously frozen. The tin cans are therefore placed for 48 hours in ice; the nitro-glycerin solidifies and, packed in a box with sponge upon the bottom, resting on four rubber tubes which come up over the cans, and well iced, it may be transported by wagon as safely as butter.

It may easily be seen from the above statements that Mr. Mowbray deals with a subject which is at once fascinating by its attendant risks and instructing by its practical value. His book is entertainingly written and cannot fail to be of great service, not only to him as a manufacturer, but also to those enterprises which, like the Hoosac and St. Gothard tunnels, require the energy of nitro-glycerin to carry them forward to successful completion.

Tables for Qualitative Chemical Analysis, *with an introductory chapter on the course of Analysis. By Professor* Heinrich Will *of Giessen, Germany.* Second American, from the Ninth German Edition. Edited by Chas. F. Himes, Ph. D., Professor of Natural Science, Dickinson College, Carlisle, Pa., 8vo., pp. 22, and Tables XIV. Philadelphia, 1874. Henry Carey Baird.

Professor Will's Analytical tables are too well known to the Chemical profession to need any detailed description of them. They have not only the great advantage which tables always afford, of presenting to the eye at a glance the complete analytical classification of the substances treated, but they have a value purely their own, over any other book in general use in the fact that all the rare as well as the common elements are included in the reactions given. Prof. Himes has done his work excellently and has made some valuable additions. He acknowledges some suggestions from Prof. Genth, of the University of Pennsylvania.

Franklin Institute.

HALL OF THE INSTITUTE, June 17th, 1874.

The meeting was called to order at 8¼ P.M., the President, Coleman Sellers, in the chair.

The Secretary being absent the President appointed J. B. Knight as Secretary *pro tem.*

The minutes of last regular meeting, held May 20th, 1874, were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at their stated meeting, held June 10th, donations to the Library had been received as follows:—

Journal of the Society of Arts, Vol 22, Nos. 1115 to 1118. London. From the Society.

Journal of the Statistical Society for March, 1874. London. From the Society.

Journal of the Chemical Society, Vol. 12, February to April, 1874, with index for Vol. 11, 1873. London. From the Society.

Proceedings of the Royal Institution of Great Britain, Vol. 7, Part 1–2, 1873, with list of Members, Officers, etc. London. From the Royal Institution.

Monthly Notices of the Royal Astronomical Society, Vol. 34, No. 6. London. From the Society.

Bulletin de la Société d'Encouragement pour l'Industrie Nationale, April, 1874. Paris. From the Society.

Zeitschrift des Ingenieur und Architekten-Vereins zu Hannover, Vol. 19, Part 4, 1873. Hannover. From the Society.

Penna. Report of the Bureau of Statistics of Labor and Agriculture, 1872–1873. Harrisburg. From the Bureau of Statistics.

Address of Henry A. Oakley, at the 8th Annual Meeting of the National Board of Fire Underwriters, held April 22d, 1874, with Reports of Stephen Crowell and Thos. H. Montgomery, and the Report of the Committee on Legislation and Taxation. New York, 1874. From the Franklin Fire Insurance Co., Philadelphia.

Bulletin of the National Association of Wool Manufacturers, January, March, 1874. Boston. From the Association.

Report of the Superintendent of the Coast Survey, during the year 1870. Washington. From E. P. Patterson, Superintendent.

Mr. Tatham, Chairman of the Committee on Exhibition, made the following report:—

"The Sub-committee on Premiums and Awards, having performed the work it was appointed to do, a motion will be made to dissolve it at the next meeting of the Committee on Exhibition.

This Sub-Committee was appointed to consider whether or not a classified list of exhibits and premiums should be published beforehand, what the premiums should be, and who should make the awards, the result of their action is embodied in the printed rules.

This statement is made publicly in order to exclude the idea, which might arise from the name of the Sub-Committee, that it has anything to do with the awards of the Judges."

Mr. Hector Orr read a paper on Street Pavements, in which he takes issue against all the present modes of paving roadways with stone, and strongly favors the use of wood. He said that the great want of the age is some street pavement that will *absorb* the concussion of vehicles passing over it.

Mr. Orr exhibited a specimen of white cedar, which had lain in the ground, as a railroad sleeper, for twenty-five years, and which is still sound. He recommended the use of white cedar for street pavements, as this would have the excellent quality of durability.

Dr. Rogers asked Mr. Orr if it was contemplated to use the cedar wood lying as a sleeper, and stated that the factor of durability as a sleeper in city railroad track was quite different from that as a pavement, and that durability in the former position does not prove that it will be so in the latter.

Mr. Close stated that he was quite positive that there are no hemlock sleepers in the street railways of Philadelphia, and asked Mr. Orr how he got his information on this point.

Mr. Orr replied, that in passing a portion of Old York Road where some repair was being made, he was told by one of the workman that the sleeper was hemlock.

Mr. Wm. B. Levan then read a paper entitled Horse Power of Steam Boilers, being a description of the Steam Engines and Horizontal tubular boilers in use by the Cocheco Manufacturing Co., Dover, N. H., and the details of a test of same, showing the following results:—

Water evaporated per pound of anthracite coal, 10 lbs. Water evaporated per indicated H. P., 18 lbs. Indicated H. P. for each cubic foot of water evaporated 3·4. Some remarks were offered by Messrs. Wiegand and Lovegrove.

The Secretary then read a paper by Mr. John Russell, upon a new process of fluxing and smelting the ores of precious metals, in which it is claimed that such ores can be fluxed at a cost not exceeding $1.00 per ton.

Dr. Rogers stated that he had not seen the process, and the paper gave no indication of what it consists, but he hardly thought such ores could be fluxed for $1.00 per ton; but if it can be done for anything like the cost named, it will certainly give a strong impetus to the production of the precious metals.

Dr. Koenig wished to know what the process was, as he saw no indication of originality, so far as it was described in the paper. If it is intended to treat all ores alike it certainly would be a failure, as it is well known that ores from different mines require different treatment, and to attempt to flux all alike would be like giving some patent medicine for the cure of all diseases.

In reply Mr. John S. Crawford stated that the process is a secret, but it was the intention of the inventor, at some future day, to lay the whole subject before the Institute.

Dr. Rogers stated that the Institute does not undertake to pass upon processes in which a secret is maintained, and recommends that the matter rest until full information is given.

The President stated that the presenting of the paper was out of order, not having passed the Committee on Meetings, but as it came to him, coupled with the names of prominent members of the Institute, he had directed it to be read.

The Secretary *pro tem.* then exhibited specimens, showing a new system of calking steam boilers, and other vessels made of sheet-metal; the invention of Mr. Jas. W. Connery, of this city, and called "Concave Calking." Also a number of specimens taken from condemned and exploded boilers, showing the injury done the metal by the old system of calking. By the new system the edges of the plates are planed, or chipped in the usual way, and a calking tool of half the thickness of the plates, having a semicircular end, is used to upset the edge of the overlying sheet, care being taken to prevent the tool coming in contact with the under plate. It is claimed that the evil known as grooving and consequent weakening of the plates, is thus entirely obviated.

Also a model of a mill for grinding wet substances, such as paints ink, and rubber, the invention of Mr. L. P. Dodge, of New York. This mill consists of two rollers, of greatly different diameters, preferably 3 to 1, with the surfaces touching, and geared to revolve at the same number of revolutions, thus causing the surfaces to slip one on the other.

Under the head of Unfinished Business, the amendment to the By-Laws, recommended by the Board of Managers, at the last Monthly Meeting, was called up, and after some discussion as to its exact bearing, by Messrs. Rogers, Le Van, Sewall, Lovegrove, Wiegand, Grimshaw, and Mitchell, the amendment was adopted with but one dissenting vote, as follows:—

Amendment to the By-Laws, Art. 2, Sect. 7.

"Members whose yearly dues are in arrears for three years, shall be considered as having resigned, and the Actuary is directed to strike their names from the list of members."

Mr. Close stated that some months ago he presented a resolution which was referred to the Committee on Science and the Arts, calling attention to the law of Congress, then just passed, allowing certain steamboats to carry 150 lbs. pressure in boilers of 42 inches diameter, made of $\frac{1}{4}$ inch iron, and inquired what had become of it.

The Actuary replied that it was referred to a Sub-committee of the Committee of Science and the Arts, but that, as several of them could not serve, a new committee would shortly be appointed.

The President read a letter from Mr. W. W. Evans, of New York, presenting to the Institute a handsomely printed copy of Brougham's Life of Washington, embellished with a colored photograph copy of a miniature portrait of Washington, painted from life by Mrs. Sharpless.

On motion of Mr. J. E. Mitchell, the President was directed to convey to Mr. Evans the thanks of the Institute for his donation.

Messrs. Hale, Kilburn & Co. placed the eulogy and portrait in a handsome frame, which they presented to the Institute.

On motion, a special meeting of the Institute was called for Wednesday, the 24th inst., at 8 o'clock P.M., for the purpose of witnessing the operation of Hall's Pulsometer, applied as a condenser for ordinary high pressure steam engines, and of an Automatic Relief valve for steam fire engines, the invention of Mr. John E. Prunty, of Baltimore.

On motion the meeting then adjourned.

J. B. KNIGHT, *Secretary pro tem.*

Civil and Mechanical Engineering.

THE THEORY OF AERO-STEAM ENGINES.*

By J. A. Henderson, M. E.

Among the possible forms of heat engines, it is probable that only those using steam and air as their working fluids, will continue as heretofore to be largely applied to practical purposes. The latter include gas engines, as the coal gas used in them merely forms the supply of fuel, and constitutes but a small fraction of the whole of the air required to act as a medium in the conversion of its heat of combustion into mechanical energy. A late publication refers to a French invention in which the expansion of oil undergoing changes of temperature, furnishes the motive force, and theoretically all liquids and even those solids, as certain of the metals, adapted to withstand the range of heat, might be so applied, but the many difficulties incurred in their practical use and construction, have prevented and will probably continue to prevent their introduction. The same may be said of ammonia engines, and bisulphide of carbon or other engines, where, in addition, special precautions have to be taken to guard against loss of their comparatively expensive working substance.

*[Editorial Note.—We publish the following paper as the first theoretical treatise on the Aero-Steam Engine which has appeared to complement the work of the late Professor Rankine on other heat engines. The article is abridged from a graduating thesis at the Stevens Institute of Technology, at the close of the college year 1872-73.

The author, who has since been employed by the Delaware Iron and Ship Building Co,, Chester, Pa., has just accepted a position at the Baltic Iron Works, St. Petersburg, Russia, under Mr. E. J. Reed, C. B., the distinguished British naval architect. His absence from the country has prevented his revision of the proofs. The paper has, however, been through the hands of his instructor, Professor Thurston, and we trust will be found to contain no serious errors.

The interest shown by engineers in the recent attempts of Warsop and others to introduce this engine will fully justify the publication of its theory, although the paper will be found more purely mathematical than those which we are accustomed to give a place to in the Journal of the Franklin Institute.]

An inspection of the relative efficiencies of air and steam, that is to say, of the proportions of the whole heat entering those working fluids, which, under given practical conditions as to temperatures, pressures, etc., can be converted into mechanical work, shows an advantage in the use of air. This is connected with the difference between a fluid, which as employed undergoes change of state from the liquid to the gaseous form, and permanent gases. It is true, as will be further on more fully shown, that it is theoretically possible with the same range of temperature, to obtain the same maximum efficiency whatever be the working fluid, but practically the conditions required to reach this maximum are much more difficult to attain in steam than in air. The steam engine however possesses, so many general advantages over the air engine, such as compactness for a given power, and durability on account of the moderate temperature of the steam, even where high pressures are used, that it will probably never be more than supplemented by any other prime mover.

As each of the fluids in these two cases, seems to have its special advantages, the question of some economic combination of the two was naturally suggested, and has been to a limited degree realized within the past few years. An increased efficiency in steam engines is said to have been attained by the injection into the boiler of a small amount of air previously passed through a heater, after the plan of Mr. Warsop, or of a portion of the products of combustion, properly freed from ash.

This subject of the use of air and steam in mixture, in the so-called "*Aero-Steam Engine*," was discussed by the late Professor Rankine in a short article republished in "Van Nostrand's *Eclectic Engineering Magazine*," for February, 1873, from a preceding number of "*The Engineer*," and entitled, "Remarks on the Theory of Air and Steam Engines."

Upon reading it about a year ago, the idea occurred to the writer, of the possibility of enclosing in a boiler, a furnace with fuel undergoing combustion under pressure, as in ordinary "Furnace Gas Engines" like Roper's or Shaw's, and of employing the joint products of combustion and steam for the working fluid, thus utilizing the whole of the heat from the fuel by saving the considerable portion which in common steam boilers is lost up the chimney, in addition to obtaining a further increase in efficiency from the air according to the statement already given.

In such a case the hot gases would first meet with the water after its formation into steam by the boiler proper. Carrying out the idea farther, the plan was suggested of injecting the hot products of combustion directly into the water, so that if desirable a still greater portion of the heat might enter the steam. This would bear some analogy to the process of injecting air into the molten metal in making Bessemer steel, and to the method of boiling water by the direct injection of steam.

Upon reference however to authorities, this idea was found not to be a new one. A patent dated in 1871, was taken out in England by a Mr. Adams, for a boiler embracing the fundamental points. It is nevertheless very elementary in form and does not seem to have its parts proportioned to their uses, as may be seen upon an examination of the drawing as given in Burgh's recent "Treatise on Boilers." Mr. Burgh has evidently expressed his convictions without looking very deeply into the theory of engines used with such a class of boilers, as he concludes his description by saying: "We here add that natural laws are entirely at variance with the above theory, and therefore have no hesitation in saying that all the steam generated in that boiler would be required for the blowing engine; consequently, the motive power is entirely absorbed in the 'working' of the boiler only."

The only other boiler of the kind to be found, was described in another part of the same work, having been patented in 1869 by Mr. Fox, an Englishman. It is a locomotive boiler to be used with liquid fuel, the air for combustion being compressed by a donkey engine with separate steam boiler, and thence passed through the fire-box and finally injected into the water. As will be seen on inspection of the drawing in Burgh's treatise, this boiler also has many defects which indicate that it had not seen service. Two points especially striking in both of these plans, are the smallness of the pipes for transmitting the air, and the want of adequate provision for combustion under pressure and the injection of the products into the water. The volume of air necessary to furnish the fuel for boilers of the sizes represented, has been far under-estimated.

Having examined those works that would be likely to give notices of such boilers, without further success than finding the above two impracticable examples, it is probable that none others, where the whole of the products of combustion are mixed with the steam, have been patented, and is quite certain that none have come into actual use.

Mr. Warsop's plan, where only a small percentage of air is injected, and which has been practically tried with increased efficiency, is one of quite a different nature.

In making a general examination into the question of the advantageous use of aero-steam engines utilizing the whole of the products of combustion, and more especially into the feasibility of constructing boilers for such engines in a practical form, the investigation may be conducted under the following heads.

1. To determine by the principles of thermo-dynamics, the theoretical efficiency, together with those other quantities of practical importance which apply to air and steam when combined in this manner, under various conditions as to pressure and temperature, and with varying proportions of air in the mixture above that necessary for complete combustion of the fuel.

2. To examine what form of mechanism would be fixed upon for a boiler to be constructed according to this plan, after full consideration of all these quantities, and to discuss the general feasibility of the project, pointing out in detail the possible advantages and the difficulties liable to be practically met with.

It is proposed in the present article to treat the first only of these divisions, as embracing essentially a theory of aero-steam engines using the whole of the products of combustion from imprisoned fuel. The results of investigation into the last division may be published separately at some future period.

Previous to taking up the direct mathematical discussion of the subject laid out before us, it would not be out of place to make a few general remarks on the efficiency of air and steam, as used in separate engines, in order that we may be better prepared to infer the results which would occur upon their being used in mixture.

The efficiency of the fluid of a heat engine is defined to be the ratio of the mechanical energy exerted by a given mass of the fluid in the engine, to the mechanical equivalent of the total heat supplied the same from the external source of heat. In order to realize the greatest possible efficiency of the fluid in any heat engine, which when working between given limits of absolute temperature τ_1 and τ_2, is known to have the value

$$\frac{T_1 - T_2}{T_1}$$

or the ratio of the range of temperature to the higher absolute limit, it is necessary that the whole reception of heat occur at the upper limit, that the whole of the rejection take place at the lower one, and as a further consequence, that the elevation of temperature between the two limits be produced by the expenditure of a sufficient quantity of mechanical work, which same amount is given out again in expansion while the working substance having received its supply of heat is falling in temperature to the lower limit. This maximum efficiency which was first demonstrated to exist by Carnot, is called by Professor Rankine, that of elementary heat engines. The difficulties arising in completely fulfilling the conditions of elementary heat engines have not been overcome in any of those engines so far constructed. The degree of approach to their practical fulfillment, varies considerably with the class to which the working fluid belongs.

Among the several kinds of air or gas engines where the fluid very nearly obeys the laws of a perfect gas, this maximum efficiency may in certain cases be theoretically reached, as in the perfect air engine of Carnot, and in Ericsson's and Sterling's engines, by the use of the regenerator as described in Rankine's treatise, but the difficulties to be encountered in the transmission of heat through the cylinder walls or through a heater at high temperatures, have thus far effectually prevented either of these engines from coming into extensive use.

In another proposed by Joule, the greatest theoretical efficiency is somewhat lessened on account of the exhaust necessarily taking place at a higher temperature than the induction at the compressing pump, but certain practical advantages are obtained which have already pushed it far more into use than any of the others just mentioned. As originally projected, this engine has never been constructed, but by a little inspection it will be seen that all of the modern furnace gas-engines such as those of Roper and Shaw, as well as Brayton's gas-engine, embody Joule's fundamental plan, viz:

First compressing the working fluid according to an adiabatic curve to an intermediate temperature, dependant upon the ratio of compression and lying between that of the external air and the highest chosen limit, then supplying heat from the fuel to further elevate it to the upper limit, expanding with constant pressure to a point of cut-off, then carrying out the expansion without gain or loss of heat to atmospheric pressure, and finally exhausting at a constant lower limit of temperature,

which, owing to the compression not having been carried on to the upper limit and the whole of the additional heat there supplied, is higher, than in the case of the "perfect engine." The formula for efficiency remains the same as for elementary heat engines, being

$$\frac{T_1 - T_2}{T_1}$$

but owing to the greater elevation of the exhaust temperature T_2, its value is reduced for the same initial temperature T_1 before expansion. The cycle of operations undergone in Joule's engine is thus fully described as being applicable to the air part of an aero-steam engine worked upon the plan here to be discussed.

The efficiency of an engine using saturated steam and expanding without gain or loss of heat would be that of an elementary heat engine were it not that a portion of the available heat supplied to the steam is wasted, so to speak, in elevating the feed water to the upper limit of temperature, the boiling point of water under the given pressure. It has been pointed out that this waste might be avoided in a condensing engine by suddenly preventing further abstraction of heat by the condenser at such a point in the return stroke that the heat due to the work of compression for the remainder of the stroke, may, while at the same time condensing the residual steam, elevate its temperature to that of the water in the boiler; the whole of the elevation will thus be produced by work of compression, and (for the same heat furnished to the steam) the work developed by expansion will be increased not only by an amount equivalent to this loss by compression, but by an additional quantity due to the increased efficiency of the engine as a whole. This mode of attaining the greatest theoretical efficiency is of course known to be entirely impracticable, but in the article "Remarks on the Theory of Air and Steam Engines" before referred to, Rankine proposes to produce an equivalent effect by making use of an excess of the heat of compression of air. The air would have to be in such quantity for the whole heat developed by its compression from the atmospheric pressure to that within the boiler, as to be sufficient for heating up the feed water to the boiling point without cooling down the air below the same temperature.

In the case of superheated steam, there is, as might be expected, an increased efficiency over saturated steam at the same pressure. But this increase by no means corresponds with that of the theoretical maximum efficiency as calculated from the limiting temperatures even when an allowance has been made for not heating up the feed water by mechanical means. Thus there is given in Rankine's treatise on the steam engine, an example of a condensing engine, where under an absolute boiler pressure of 34 lbs per square inch, corresponding to a boiling point of 257·5° Fahrenheit, the efficiency of the steam when used in the saturated state was 0·128, and when further superheated up to 428° was 0·145, being greater than the previous value only in the ratio of 1·18 to 1, whereas, according to calculations based merely on the range of temperature as for elementary heat engines, the ratio of increase should be between 2 and 3, the temperature of condensation remaining the same. The cause of the comparative smallness in this departure from the efficiency of saturated steam, even when superheating is carried on to double or treble the actual range of temperature, seems to be that when the heat being supplied to any engine has once fallen in grade to any fixed lower temperature, it is impossible to get a theoretical maximum efficiency for this heat, corresponding to an upper limit higher than this temperature. In the present case of superheated steam, the great mass of the heat supplied is used in evaporating the water, and consequently can not have a maximum efficiency greater than that due to a range between the boiling point and the temperature of condensation, while only the remaining small fraction of heat used in superheating can really be considered in connection with the excess of temperature above the boiling point. This explanation would thus, in a general way, account for the comparatively slow increase in efficiency of superheated steam with temperature added in superheating, and it shows furthermore that for the same highest limit of temperature, steam will become more efficient in proportion as it is less superheated by increasing the pressure and so elevating the boiling point. These remarks will afterwards be made use of in explaining the increase of efficiency with pressure in the case of aero-steam engines.

In taking up the subject proper of this essay, the question primarily to be considered, is to what extent air can be mixed with steam and the steam in the combined fluid efficiently condensed, or more particularly whether a boiler injecting into the steam such a proportion of air as the whole of the products of combustion, can be used with a condensing engine.

The size of the lifting air-pump will of course have to be increased in the direct ratio of the quantity of air introduced, and its volume must be that of the air to be ejected at the diminished pressure and temperature of the condenser. Where the proportion of steam largely exceeds that of the air, as in Warsop's plan, it is very probable that as far as the air-pump is concerned, a condensing engine could be employed, but in the present case although the resistance of the pump might be fully compensated by the increased efficiency, its volume would have to be so far increased as to render its use impracticable. This may be inferred from the results obtained by calculation in one of the subsequent examples, where although the least amount of air necessary for complete combustion was used, the condenser air-pump when single-acting would have to be 2·7 times, or when double-acting 1·35 times the volume of the main double-acting aero-steam cylinder. The latter itself has to be made larger than if the steam alone were yielding the same power, by a volume about equal to that of the compressing pump for the boiler. There is also another element to be considered, which although advantageous for efficient expansion in unjacketed cylinders, may put a stop to the use of condensation, even when but a comparatively small quantity of air is in mixture; and this is the retardation which the air offers to the transfer or rush of steam to the condensing surfaces.

These two serious objections of size of pump and non-efficiency of condenser indicate that it would be here impracticable to make use of condensation, and on this account the calculations and formulæ will only refer to non-condensing engines.

It might be here mentioned, that in such engines although the expansion is not carried out beyond the atmospheric pressure, owing to the tension of the steam being but a fraction of that of the working mixture, the temperature of exhaust may be carried considerably below 212° before condensation occurs, and the increased efficiency which a condenser commonly obtains by lowering the temperature of rejecting heat below that same point, thus partially realized. It might be wholly realized were the air in sufficient excess.

The case to be discussed is thus restricted to that of a high-pressure aero-steam boiler and engine of the following general description:

The boiler would be provided with an enclosed furnace, from which the whole products of combustion under pressure, would be injected into the water and there so lowered in temperature at the expense of further formation of steam, that when thoroughly mixed with all of the steam formed, a given final temperature of super-heating would be produced.

The engine would consist essentially of a main working cylinder using this mixture expansively to atmospheric pressure, an air compressing pump to supply the imprisoned fuel at the boiler pressure, and of the mechanism by which the two would be connected and the excess of work delivered.

To be continued.

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THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

[Continued from vol. lxvii., page 401.]

Penciling is the first and the most important operation in drafting; it requires more skill to produce neat pencil work than to "ink in" the lines after the penciling is done.

The beginner, unless he exercises the greatest care in penciling a drawing, will have the disappointment to find the paper soon becoming dirty from plumbago, and the pencil lines crossing each other at all angles, so as to give the whole a slovenly appearance.

He will also, unless he stops to consider the nature of the operation in which he is engaged, make the mistake of regarding the pencil work as a preliminary part, instead of constituting, as it does, the main drawing, and will thereby neglect that accuracy which alone can make either a good looking or a valuable drawing.

The pencil work is indeed the main operation, the inking being merely to give distinctness and permanency to the lines. The main thing in penciling is accuracy of dimensions and stopping the lines where they should terminate, without crossing others.

The best pencils only are suitable for drafting; if the plumbago is not of the best quality, the points require to be continually sharpened, and the pencil is worn away at a rate that more than makes up the difference in cost between fine and cheap pencils, to say nothing of the effect upon the drawing.

It is common to use a flat point for drafting pencils, but a round one will be found quite as good if the pencils are fine, and quite a convenience is gained by a round point for free hand use in making short rounds and fillets.

A pencil by Faber that has detachable points, which can be set out as they are worn away, is convenient for drafting.

For compasses the lead points should be cylindrical, and fit into a metal sheath without paper packing or other contrivance to hold them, and if an apprentice has instruments that are not arranged in this manner, he should have them changed at once, both for convenience and economy.

The ink used in drawing should always be the best that can be procured; without good ink the draftsman is continually annoyed by the imperfect working of pens, and the washing of the lines if there is shading to be done.

The quality of ink can only be determined by experiment; the perfume that it contains, or tin foil wrappers and Chinese labels, are no indication of quality; not even the price, unless it be with some first-class house.

To prepare the ink, I can recommend no better plan of learning than to ask some one who understands the matter. It is better to waste a little time in grinding than to be at a continual trouble with pens, which will occur if the ink is ground too rapidly or on a rough surface.

To test ink, draw lines on the margin of the sheet, note the color, how the ink flows from the pen; after the lines have dried, cross them with a wet brush. If they wash readily the ink is too soft; if they for a time resist the water and then wash tardily, the ink is good. It cannot be expected that inks soluble in water can permanently resist its action after drying; in fact, it is not desirable that drawing ink should do so, for in shading, the outlines should be blended into the tints where the latter are deep, and this can only be effected by washing.

Pens fill themselves by capillary attraction if they are first made moist by being dipped into water; they should not be put into the mouth to wet them, as there is danger of poison from fancy inks, and the habit is not a neat one.

In drawing lines keep the pen nearly vertical, leaning just enough to prevent it from catching on the paper. Beginners have a tendency to hold pens at an angle, and drag them on their side, but this will not produce clean sharp lines, nor allow the lines to be made near enough to the square blades or set squares.

In regard to the use of the T square and set squares, I can give no rules except to observe others, and experiment until convenient customs are attained. A beginner should be careful of contracting unusual habits, and, above all things, of making important discoveries as to new plans of using instruments, or that common practice is all wrong, and that it is left for him to develop the true and proper way of drawing. This is a kind of discovery which is very apt to intrude itself at the beginning of an apprentice's course in many things beside drawing, and often leads him to do and say that which he will afterwards wish to recall.

It is generally a safe rule to assume that any custom long and uniformly followed by intelligent people, is very apt to be right; and, in the absence of that experimental knowledge that alone enables us to judge, it is safe to receive such customs, at least for a time, as being correct.

Without any wish to discourage the ambition of the apprentice, which always inspires him to laudable exertion, I nevertheless think it best to caution him against innovations. The estimate formed of our abilities is very apt to be inversely as our experience, and old engineers are not nearly so confident in their deductions and plans as beginners are.

A drawing being inked-in, we come next to dimension and centre lines. The centre lines should be in red ink, and pass through all points of the drawing that have an axial centre, or where the work is similar and balanced on each side of the line. This rule is a little obscure, but will be best understood if studied in connection with a drawing, and perhaps as well remembered without further explanation.

Dimension lines should be in blue, but may be in red. How and where to put them is a great point in drafting. To know where to put dimensions must involve a knowledge of fitting and pattern-making, and cannot be explained here; make faint lines, leaving a space in their centre for figures, when long enough. Study the distribution of centre lines and dimensions over the drawing, for the double purpose of giving it a good appearance and to avoid confusion. Learn to make figures like printed numerals; they are much better understood by the workman, look more artistic, and when learned take but little if any more time than plain figures. If the scale is feet and inches, write dimensions to three feet in inches, and above this in feet and inches; this corresponds to shop custom, and is more comprehensive to the workman, however wrong it may be according to other standards.

In sketches and drawings made by the apprentice, such as are not intended for the shop, it is suggested that metrical scales be used, because such scales will not interfere with feet and inches, and it will prepare the mind for the introduction of this system of lineal measurement, which is quite sure in time to be adopted in England and America, as it has been in many other countries.

In shading drawings, be careful to put on little enough, and to put it in the right place; many will contend, and not without good reasons, that working drawings need no shading; yet it will do no harm to learn how and where they can be shaded: it is better to omit the shading from choice than from necessity. Sections must, of course, be shaded—not with lines, although I fear to attack so old a custom, yet it is certainly a tedious and useless one; sections with light ink shading of different colors, to indicate the kind of material, are easier to make and look much better. By the judicious arrangement of a drawing, a large share of it may be in section, which, in almost every case, are the best kind of view to work by. The proper coloring of these sections gives a good appearance to the drawing, and conveys the idea of an organized machine, or, to use the shop term, "it stands out from the paper." In shading sections, leave a margin of white between the tints and the lines on the upper and left-hand sides of the section; it breaks the connection and sameness, and the effect is striking; it separates the parts, and adds greatly to the clearness and general appearance of the drawing.

Cylindrical parts in the plane of sections, such as shafts and bolts, should be drawn full and have a "round shade," which, with blue tint, relieves the sameness of appearance, a point to be avoided in sectional views.

Conventional custom has assigned blue as the tint for wrought iron, neutral or pale pink for cast iron, and purple for steel. Wood is generally distinguished by "graining," which is easily done, and looks well.

The title of a drawing is a feature that has much to do with its appearance, and the impression conveyed to the mind of an observer; and, while it can add nothing to the real value, it costs so little to make plain letters, that the apprentice is urged to learn this as soon as he begins to draw, not to make fancy letters, nor indeed any kind except plain block letters, which can be rapidly laid out, and consequently used to a greater extent. By drawing six parallel lines, making five spaces, and then crossing them with equidistant lines, the points and angles in block letters are determined; and after a little practice it becomes the work of but a few minutes to put down a title or other matter on a drawing so that it can be seen at a distance, and read at a glance in searching for sheets or details.

In the manufacture of machines, there are usually so many sizes and modifications, that the drawings must assist and determine, in a large degree, the completeness in matters of classification and record. Taking the manufacture of machine tools for example: we cannot well say, each time we want to speak of them, a thirty-six inch lathe without screw and gearing, a thirty-two inch lathe with screw and gearing, a forty-inch lathe triple geared or double geared, with twenty or thirty foot bed, and so on. To avoid this it is necessary to assume symbols for machines of different classes, consisting generally of the letters of the alphabet, qualified by a single number that designates capacity and different modifications. Assuming, in the case of engine lathes, that A is the symbol for lathes of all sizes, those of different capacity and modification would be represented in the drawings and records as A^1, A^2, A^3, A^4, and so on, the letter and numerals together requiring but two characters to indicate a lathe of any kind. These symbols should be marked, in large, plain letters, on the left-hand lower corner of the sheet, so that the manager or workman or any one else can see at a glance what the drawing relates to. This symbol should run through the time-book, cost account, sales record, and be the technical name for the machines, which should always be spoken of in the works by the name of their symbol.

In making-up time a good plan is to supply each workman with a small slate and pencil, on which he enters his time as so many hours charged to the respective symbols. Instead of interfering with his time, this will increase the workman's interest in what he is doing, and naturally lead to a desire to diminish the time charged to the various symbols.

When the symbols are added to a drawing, the next thing is the "pattern numbers." These should be marked in prominent, plain figures on each piece of casting, either in red ink or other color that will contrast with the general face of the drawing. These pattern numbers, to avoid the use of symbols in connection with them, must include consecutively all patterns used in the business; these numbers can extend to thousands without inconvenience.

A book containing the pattern record should be kept by the head draftsman, in which these numbers are set down, with a short description to identify parts to which the numbers belong, so that various details can at any time be referred to. Besides this description, there should be, opposite the catalogue or pattern numbers, ruled spaces, in which to enter the weight of castings, the cost of the pattern and, if needed, the amount of turned, planed or bored surface on each piece when it is finished.

In the same book the assembled parts of each machine should be set down, in a list, with its symbol and descriptive name, so that orders for castings can be made from this list without other references.

This system is the best one known to the author, and is in substance the plan now adopted in some of the best engineering establishments. It may be susceptible of improvement; he hopes it is; but let the apprentice seize on the idea of some system at the beginning; any plan is better than none, and the schooling of the mind to be had in the observance of systematic rules is the great point in view. New plans for promoting system may at any time arise, but they cannot be at any time understood and adopted except by those who have cultivated a taste for order and regularity.

In regard to shaded elevations, it may be said that photography has superseded them for the purpose of illustrating machinery, and but few establishments care to incur the expense of ink-shaded elevations.

Ink shading cannot be done with various degrees of care, and in a longer or shorter time; there is but one standard for it, and that is that such drawings should only be made with great care and skill.

A shaded elevation, although it may surprise and please the unskilled, is execrable in the eyes of a draftsman or an engineer, unless it is a good one; and, as the making of shaded elevations can be of but little assistance to an apprentice draftsman, it is better to save the time that must be spent in order to make a good drawing and apply the same study and time to other matters of greater importance.

It is not assumed that shaded elevations should not be made, nor that ink shading should not be learned, but to insist on the greater importance of other kinds of drawing, which is too often neglected to gratify a taste for picture-making that has but little to do with mechanics.

Isometrical perspective is often useful in drawing, especially in wood structures when the material is of rectangular sections and disposed at right angles, as in machine frames. One isometrical view, which can be made nearly as quickly as a true elevation, will show all the parts, and can be figured for dimensions the same as plane views.

True perspective, although never necessary in mechanical drawing, may be studied with advantage in connection with geometry, and often lead to the explanation of problems in isometric drawing, and will also assist in free hand lines that have often to be made to show parts of machinery that are oblique to the regular planes.

This far the remarks on drafting have been confined to manipulation mainly. Unlike most branches of engineering work, drafting must as an art consist mainly in special knowledge, and is not capable of being learned or practiced upon general principles. It is therefore impossible to give the learner much aid by searching after principles, and the few propositions that follow comprehend nearly all that can be explained in words.

Geometrical drawings consist in plans, elevations and sections ; plans being views on the top of the object in a horizontal plane ; elevations, views on the sides of the object in vertical planes, and sections, views taken on bisecting planes, at any angle through the object.

Drawings in true elevation or in section are based upon flat planes, and give dimensions parallel to the planes in which the views are taken.

Two elevations taken at right angles to each other, fix all points, and give all dimensions of parts that have their axis parallel to the planes on which the views are taken ; but when a machine is complex, or when several parts lie in the same plane, three and sometimes four views are required to display all the parts in a comprehensive manner.

Mechanical drawings should be made with reference to all the processes that are required in the construction of the work, and the drawings should be responsible, not only for dimensions, but for unnecessary expense in forging, fitting, pattern-making, and moulding.

Every "piece" that is laid down has something to govern it that we will term a "base," some condition of functions or position that, if understood, will suggest its size, shape, and relation to other parts. By searching after a "base" for each and everything, we proceed upon principles, avoid error, and continually maintain a test of what is done. Every wheel, shaft, screw or piece of framing should be made with a clear view of the functions it has to fill, and there are always reasons why such parts should be of a certain size, have such a speed of movement, or a certain amount of bearing surface. These reasons or conditions may be classed as *expedient*, *important*, or *essential.*

I now come to note a matter in connection with drafting to which the attention of the apprentice is earnestly called, and which if he neglects, all else may be useless. I allude to indigestion, and its resultant evils induced by drafting. All sedentary pursuits give rise to this trouble, but none of them can compare with drafting, where every condition in the way of promoting this derangement exists.

In drafting, the muscles are at rest, circulation is slow, the mind is intensely occupied, robbing the stomach of its blood and vitality, and worse than all, the mechanical action of the stomach is arrested by leaning over the edge of the drafting board. I regret my inability to give any fixed rule to avoid this danger, but am at the same time confident that any apprentice who understands the danger can avert it by applying some of the logic which has been recommended in the study of mechanics. We can conclude that if anything tends to induce indigestion, its opposite tends the other way, and will arrest it; if stooping over the drafting-board interferes with the action of the digestive organs, leaning back does the opposite; therefore keep your doard as high as possible, stand at your work, and cultivate a constant habit of straightening up and throwing your shoulders back; if possible, take brief intervals of vigorous exercise.

Like rating the horse-power of a steam engine, by multiplying the force into the velocity, we must estimate the capacity of a man by multiplying his mental acquirements into his vitality. Latent power is of no use, neither is latent knowledge or skill.

Physical strength, bone and muscle, must be one of the elements in successful engineering experience, and a store of these things must be laid in at the same time with a mechanical education, or it will be found that when ready to enter upon a course of practice, that most important element, the propelling power, has been omitted.

PATTERN MAKING AND CASTING.

Patterns and castings are so intimately connected that it would be difficult to treat of each without continually confounding them together; it is therefore proposed to combine patterns and moulding under one head. Every operation in the pattern shop has reference to some operation in the foundry, and patterns considered separately from moulding operations would be incomprehensible to any but the skilled.

Next to designing and drafting, pattern making is the most intellectual of what has been termed engineering processes—the department that must include the exercise of the greatest amount of personal judgment on the part of the workmen, and at the same time demands a high grade of hand skill.

In every other department there are drawings furnished, and the plans of the work are dictated by the engineering department of machinery-building establishments, but the pattern-maker makes his own plans for constructing patterns, and has even to reproduce the drawings of the fitting shop to work from. Nearly everything pertaining to patterns is left to be decided by the pattern-maker, who from the same drawings and through the exercise of his judgment alone, makes patterns that are durable and expensive, or temporary and cheap, as the probable extent of their use may determine.

The expense of patterns should be divided among and charged to the machines for which the patterns are used, but there can be no constant rules for assessing or dividing this cost. A pattern may be used but once, or it may be used for years; it is continually liable to be superseded by changes and improvements that cannot be predicted before hand; and in making patterns the question of how much ought to be expended on them continually arises—a matter that should be mutually determined by the engineer and the pattern-maker, but is generally left to the pattern-maker alone, for the reason that but very few mechanical engineers study and learn pattern-making so well as to dictate the construction of patterns.

To point out to the apprentice some of the leading points or conditions to be taken into account in pattern-making and which must be understood in order to manage this department, I will refer to them in consecutive order.

First.—Durability, plans of construction and cost, which all amount to the same thing. To determine this point, there is to be considered the amount of use that the patterns are likely to serve, whether they are for standard or special machines, and the quality of the castings so far as affected by the patterns. A first-class pattern framed to withstand moisture and rapping, may cost twice as much as another that has the same outline ; yet the cheaper pattern may answer almost as well to form a few moulds as the expensive one

Second.—The cast and manner of moulding is determined by the patterns, which may be parted so as to be 'rammed up' on fallow boards or a level floor, or the patterns may be solid and have to be bedded, as it is termed ; pieces on the top may be made loose, or fastened on so as to 'cope off;' patterns may be well finished so as to draw clean, or rough so that the mould will require a great deal of time to finish after the pattern is removed.

Third.—The soundness of such parts as are to be planed, bored and turned in finishing ; this is also a matter that is determined mainly by how the patterns are arranged, by which is the top and which the drag, or bottom side as determined by the manner of drawing, and the provisions for avoiding dirt and slag.

Fourth.—Cores where used, how vented, how supported in the mould, and I will add how made, because cores that are of an irregular form are often more expensive than the external moulds, including the patterns. The cost of patterns is often greatly reduced and sometimes increased, by the use of cores, which may be used either to cheapen patterns, add to their durability, or to insure soundness in the castings.

To be continued.

ON THE STRENGTH OF MATERIALS.

By Chief Engineer Wm. H. Shock, U. S. Navy.

In designing some boilers for high steam, I was anxious to obtain the necessary strength with a minimum amount of metal, economy of weight being a necessary, if not an absolute condition, and having no reliable data at hand from which to ascertain the "detrusive strength" or resistance to shearing of certain size bolts, I instituted a series of very carefully conducted experiments on bolts of various dimensions, under the two possible conditions in which they might be used in connection with the bracing of boilers, and for other purposes; i. e., when used as shown in fig. 1, double cut, or as in fig. 2, single cut.

FIG. 1

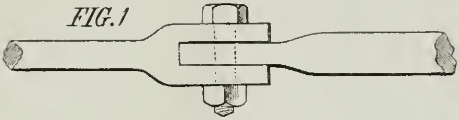
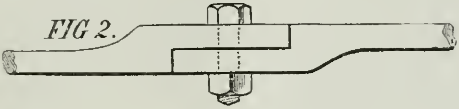


FIG 2.



The bolts, sixty in number, (twelve each of the following shop dimensions, viz., 1, $\frac{7}{8}$, $\frac{3}{4}$, $\frac{5}{8}$ and $\frac{1}{2}$ inch diameters) were forged in the usual manner without any reference whatever to the experimental tests to be made. The material used was the ordinary bar-iron of commerce, my great wish being to obtain the data sought for, under conditions of actual practice.

When the bolts were received in the experimenting room, they were carefully measured with "vernier calipers," numbered, and drawings made of them with dimensions marked on.

The testing machine used belonged to the Ordnance Department at the Navy Yard, Washington, and is an instrument of very delicate adjustment.

The barometrical, as well as the thermometrical conditions, were uniform during the experiments.

The attachments (see plate I—figs. *a,a—b,b—c,c*—and *d*) were hardened, the inner angles of the holes being slightly rounded, or counter-sunk, to avoid the otherwise "knife edge" being brought to bear on the bolts, thus bringing the experimental specimens under conditions approximating actual practice.

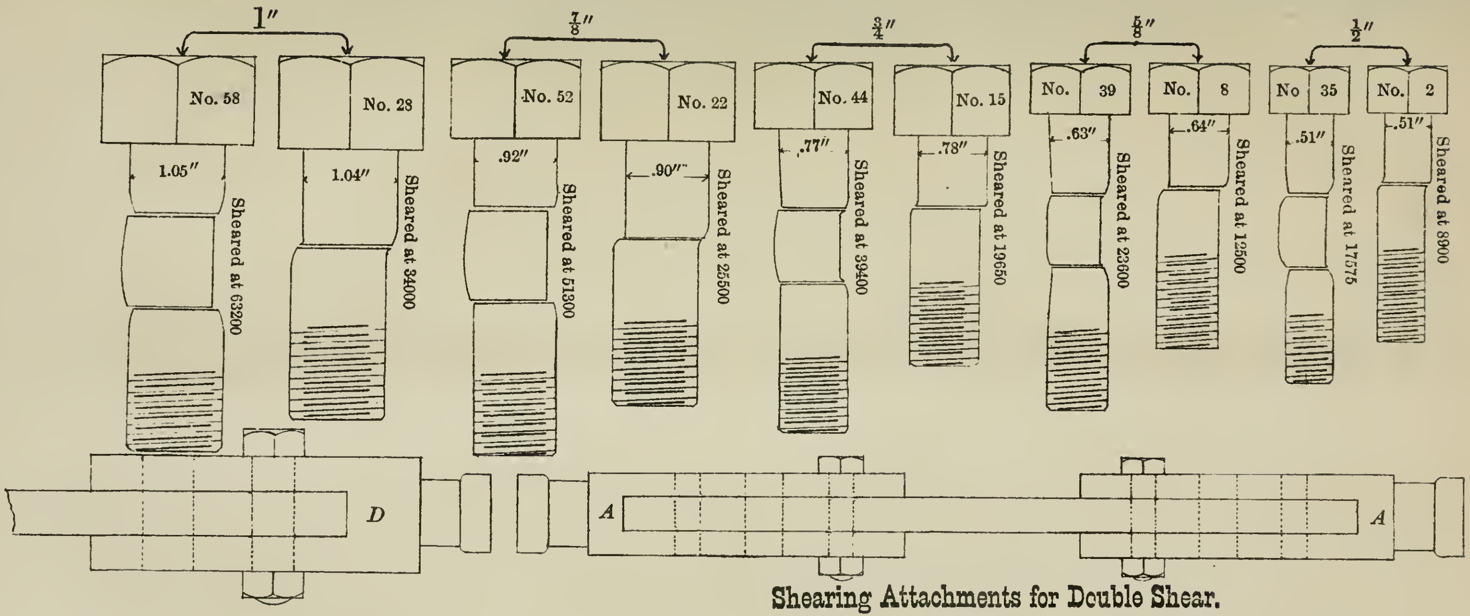
The character of the fracture in the several specimens was singularly uniform; those shown in plate I being correct exponents of the rest.

The following tabular statement shows the results obtained:

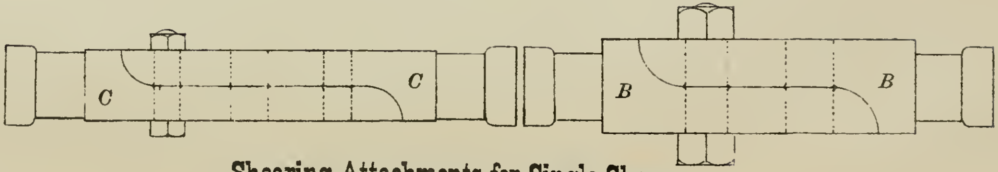
RESULTS OF EXPERIMENTS ON SHEARING STRAINS OF IRON BOLTS.

SINGLE SHEAR.					DOUBLE SHEAR.				
Number of Exp.	Actual Diameter of Bolt. inches.	Actual Shearing Strain. lbs.	Area of Mean Section. sq. ins.	Shearing Strain per Square inch of Section. lbs.	Number of Exp.	Actual Diameter of Bolt. inches.	Actual Shearing Strain. lbs.	Area of Mean Section. sq. in.	Shearing Strain per Square inch of Section. lbs.
1	·51	9000	......	......	31	·51	16175	......	......
2	·51	8900	......	......	32	·51	16800	......	......
3	·52	9400	......	......	33	·50	16050	......	......
4	·52	9400	......	......	34	·52	16400	......	......
5	·52	9400	......	......	35	·51	17575	......	......
6	·51	9000	......	......	36	·51	17600	......	......
Mean	·515	9183·3	·20831	44085	Mean	·51	16766·6	·40856	41036
7	·64	12900	......	......	37	·65	25650	......	......
8	·64	12500	......	......	38	·63	23700	......	......
9	·64	13300	......	......	39	·63	23600	......	......
10	·66	12750	......	......	40	·63	24800	......	......
11	·65	12650	......	......	41	·63	24600	......	......
12	·65	12750	......	......	42	·64	24300	......	......
Mean	·6466	12808·3	·32837	39006	Mean	·635	24442	·63338	38589
13	·78	18800	......	......	43	·78	36650	......	......
14	·78	19500	......	......	44	·77	39400	......	......
15	·78	19650	......	......	45	·78	37700	......	......
16	·79	18800	......	......	46	·76	36400	......	......
17	·78	19000	......	......	47	·78	36650	......	......
18	·79	18400	......	......	48	·79	39400	......	......
Mean	·7833	19025	·48192	39477	Mean	·7766	37700	·94751	39789
19	·91	27600	......	......	49	·91	51600	......	......
20	·90	26600	......	......	50	·92	47650	......	......
21	·89	26550	.....	......	51	·93	46200	......	......
22	·90	25500	......	......	52	·92	51300	......	......
23	·91	26425	......	......	53	·91	52000	......	......
24	·91	26700	......	......	54	·91	51375	......	......
Mean	·9033	26562·5	·64089	41446	Mean	·9166	50021	1.31988	37822
25	1·03	33000	......	......	55	1·03	64000	......	......
26	1.04	34800	......	......	56	1·03	61700	......	......
27	1·04	35650	......	......	57	1·04	63550	......	......
28	1·04	34000	......	......	58	1·05	63200	......	......
29	1·04	35800	......	......	59	1·03	63525	......	......
30	1·03	32900	......	......	60	1·03	63500	......	......
Mean	1·036	34358·3	.84395	40071	Mean	1·035	63246	1.68268	37586
Mean of the above				40817	Mean of the above				38984

Mean of both Sets $\frac{40817+38984}{2} = 39900$



Shearing Attachments for Double Shear.



Shearing Attachments for Single Shear.

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Chemistry, Physics, Technology, etc.

EXPERIMENTS ON THE TENACITY OF MALLEABLE METALS AT VARIOUS TEMPERATURES.

By M. A. Baudrimont.

[*Translated from the Annales de Chimie et de Physique, Series* III, *Vol.* xxx, *page* 304, 1850, *by Chief Engineer B. F. Isherwood, U. S. N.*]

To the Editor of the Journal of the Franklin Institute:—

Dear Sir: The following memoir on the tensile strength of the principal malleable metals at different temperatures, addressed by its author to the Academy of Sciences at Paris, seemed to me to contain so much both curious and useful in engineering, that I have translated it for the Journal, as it has never before appeared in English. The results with iron in particular are very singular in many respects, proving that metal to be an exception within certain limits—and the only one so far as known—to the general law of decreasing tenacity in function of increasing temperature.

The ingenious experimenter has omitted to state whether he experimented on the same piece of iron wire at the different temperatures, or on different pieces; and, if the former, whether he experimented first at the lower and afterward at the higher temperatures, or the reverse; for, if he experimented with the same piece of wire, and at the lower temperatures first, as was probably the case, the results are not quite conclusive, as will appear from the following considerations:

That no piece of iron wire has precisely the same tenacity at every point of its length, is absolutely certain; consequently, there must be a weakest point, a next weakest, and so on. Now when the wire is first stretched to rupture, it will yield at the weakest point, showing a certain tenacity. If it be thus stretched again it will yield at the next weakest point, showing a greater tenacity than the previous one, and so on, showing for each successive stretching an increased tenacity. If the first stretching takes place at the lower temperature and the next at the higher one, the difference in the two tenacities shown, is attributed to the difference of temperature, whereas it may be due to the fact that the wire at the point of rupture in the second case, had, for equal temperatures, a considerably greater tenacity than at the point of rupture in the first case. What is really shown by such experiments, is the difference of the tenacities at the two points of successive rupture with equal temperatures, modified by the influence of the different experimental temperatures.

The experiments made on the tensile strength of wrought iron in 1837 by a Committee of the Franklin Institute, had first shown the anomalous fact of its increase with the increase of temperature between certain limits of the latter. And, in 1853, Mr. Fairbairn published his experiments, demonstrating the same truth. These, together with the experiments made by Baudrimont in 1843, and detailed in the following memoir, constitute all the knowledge we possess on the subject.

In the experiments by the Committee of the Franklin Institute, however, the same piece of iron was successively ruptured, and gave, as a general result just what might have been expected, namely, increasing tenacity at each rupture under ordinary atmospheric temperatures; but the Committee failed to detect the reason, and left the naked fact standing in their tables without explanation. The experiments made by the Committee under high temperatures, were vitiated by the same cause, as they were made on the same piece of iron after it had been broken—often several times—under low temperatures. The Committee did not perceive that the greater tenacity of the iron observed under the high temperature might be due to the fact that the iron was then necessarily fractured at a stronger point than under the preceding low temperatures; but they compared, in all cases, the tensile strength obtained from the first trial under low temperatures, with the tensile strength obtained under the high temperature often after several fractures had been made under the low temperature and the weakest points thereby eliminated. The tenacity thus found under the high temperature, was of course, as much too great, comparatively, as the tenacity under the low temperature, for the number of fractures made, exceeded the tenacity at the first fracture under the low temperature. Yet, obvious as is this deduction, the Committee ignored it and attributed the entire increase of tenacity shown under the high temperature to the influence of that temperature alone, while, in fact, this increase was mainly, if not wholly, due to the elimination of the weakest points by the several previous fractures of the iron made under low temperatures.

As far as I am aware, this fact of the necessarily increasing tenacity of the iron at successive fractures as a consequence of the continued elimination of weaker points by each preceding fracture, is now pointed out by me for the first time. The failure to perceive it, caused Professor Walter R. Johnson to attribute an actual increase of strength conferred on the iron by the simple process of stretching, whereas this result was solely due to the removal of weak points. Combining this error with that of the increase of strength assumed to be due to high temperatures, but really due to the same cause, led him to propose what he termed the "thermo-tension" treatment of iron as a means of increasing its tenacity. The whole principle of his process, however, being based on fallacious assumptions, its practical application proved worthless.

The conditions under which the experiments of Mr. Fairbairn were made, and particularly the fewness of their number, do not, in my opinion, justify any positive conclusions.

From a careful comparison of all the experiments I have been able to collect concerning the influence of temperature on the tenacity of wrought iron, there results that, between the temperatures of zero and 550 degrees Fahrenheit, this influence is exactly null, developing the important practical fact that, between these limits, no provision need be made by the engineer for effect of differences of temperature.

B. F. ISHERWOOD,

Chief Engineer, United States Navy.

About sixteen years ago, I conceived an idea that the laws of the cohesion of homogeneous substances, that is to say those laws which control the reciprocal action of their molecules, might be ascertained experimentally. The idea could not be immediately realized in consequence—as always happens in opening a new road—of the numerous obstacles to be in turn surmounted before advancing farther. In order, therefore, to overcome the difficulties that opposed the accomplishment of my project, I made a programme of the indispensable preparatory researches requiring completion before an approach could be even commenced toward my principal object which included the investigation of the constitution of wire-drawn metals, and of their elasticity and tenacity. In 1835, I had the honor to communicate to the Academy the researches on the constitution of wire-drawn metals, which have been inserted in the "*Annales de Chimie et de Physique,*" 2d series, tome lx.

There resulted from these first researches, that metals acquire permanent properties only after careful annealing, and that the different methods of working them, such as hammering, rolling and wire-drawing, by causing notable changes in their volume, produce, at the same time, considerable modifications in their tenacity.

In April, 1837, I undertook experiments on the elasticity of metals. They were made by the method of stretching, for copper, iron, silver, platinum, gold, lead and tin. I found from those experiments, conducted by a process easy and exact to put in practice, that the lengthening of wire-drawn metals was proportional to the weights applied up to the instant of rupture; a result which M. Wertheim has since obtained from a series of observations not less numerous and not less positive.

I have not been able to publish these experiments because, in a theft committed at my house, the instrument used for measuring the relative diameters of the wires was stolen, and unfortunately I did not know its unit. Nevertheless, I had obtained sufficient results for the object proposed, and for even still more.

It was only in 1843 that I could undertake the third set of experiments, the one relative to the tenacity of the metals and which is the subject of the present memoir. Since that date, M. Wertheim has published the results of researches analogous to mine, but as he did not experiment at the temperature of 32 degrees Fahrenheit, and has left omissions in relation to copper and palladium, besides not having operated by the same process, I believe I ought to submit them to the judgment of the Academy.

The metals experimented on were copper, gold, platinum, silver, palladium and iron. They were drawn into wire, and all, with the exception of the iron, made to pass through the same hole. The iron wire was smaller, because otherwise it would have required too great a weight to fracture it.

I operated successfully at 32 degrees Fahrenheit in melting ice, at 212 degrees Fahrenheit in boiling water, and at 392 degrees Fahrenheit in an oil-bath heated very slowly, the temperature of which was measured by a mercurial thermometer.

The wires had been annealed with a great deal of care, and were placed horizontally in a cast-iron vessel containing the liquid forming the bath. This vessel was suspended by weights attached to chains passing over pullies, which allowed it to be raised or lowered at will for conveniently arranging the wires within it. The furnace for heating the liquid when operating at the high temperatures, was mounted on a wheeled frame-work so that it could be instantly run on one side in order to lower the vessel.

The wires being small in diameter, and good conductors of heat, would evidently quickly acquire the temperature of the bath, and remain constantly at it notwithstanding the heat developed by the stretching to which they were subjected. One of their extremities was fixed immovably to an iron support; and the other, by means of a light strong chain guided by three pullies, was attached to a zinc receiving-pan, into which dry sand was arranged to run from a box containing it, with a velocity controllable at will by a more or less inclination of the box. When the wire was ruptured, the zinc pan, in falling, struck a handle which closed a valve that instantly arrested the flow of sand. The zinc pan and the sand it contained, were then weighed on a well-made, strong, and very sensitive balance.

The diameter of the wires was measured at the temperature of 60·8° Fahrenheit by callipers sensitive to the $\frac{1}{2540}$ of an inch.

The direct results of the experiments are given in the following tables:

Diameter of the Wires at 60·8° Fahrenheit.

Copper - - - -	0·017 716 860	inch.
Gold - - - - -	0·016 240 455	"
Platinum - - - -	0·016 142 028	"
Silver - - - - -	0·015 679 421	"
Palladium - - - -	0·015 649 893	"
Iron - - - -	0·006 889 890	"

Experiments on the Tenacity of Wire-Drawn Metals at 32° Fahrenheit.

Name of the Metal.	Duration of the Experiment in Minutes & Seconds.	Weight, in pounds, producing rupture of the Wire.	Mean of the Weights.
Copper,...........	6·38	10·108 720 000	10·015 018 666
	9·10	9·921 317 333	
Gold,.............	2·37	5·613 260 877	5·421 448 741
	2·24	5·150 266 067	
	2·36	5·500 819 280	
Platinum,.........	2·20	6·468 698 905	6·585 549 976
	2 40	6 702 401 047	
Silver,............	2·39	7·859 888 070	7·779 047 706
	2·26	7·760 674 896	
	2·32	7·716 580 153	
Palladium,........	3·29	10·119 743 686	9·981 947 612
	3·19	9·844 151 538	
Iron,.............	3·40	10·975 181 714	10·886 441 042
	3·53	11·125 103 843	
	4·30	10·847 306 957	
	3.44	10·598 171 655	

Experiments on the Tenacity of Wire-Drawn Metals at 212° Fahrenheit.

Name of the Metal.	Duration of the Experiment in Minutes & Seconds.	Weight, in pounds, producing rupture of the wire.	Mean of the Weights.
Copper,	2·56	8·768 239 797	8·725 798 601
	3·90	8·666 821 880	
	2·55	8·796 901 374	
	2·57	8·671 231 354	
Gold,	2·11	4·528 530 181	4·487 375 087
	2·11	4·645 381 252	
	3·47	4·288 213 828	
Platinum,	3·28	5·280 345 562	5·613 260 877
	1·36	5·943 971 454	
	1·35	5·615 465 614	
Silver,	1·51	6·149 012 013	6·388 777 182
	2·40	6·735 472 104	
	1·53	6·395 942 578	
	2·29	6·274 682 033	
Palladium,	3·35	9·001 941 932	8·888 397 967
	3·60	8·774 854 002	
Iron,	3·35	10·099 901 051	10·165 491 982
	3·25	10·066 829 993	
	4·12	9·835 332 589	
	3·46	10·659 904 297	

Experiments on the Tenacity of Wire-Drawn Metals at 392° Fahrenheit.

Name of the Metal.	Duration of the Experiment in Minutes & Seconds.	Weight, in pounds. producing rupture of the Wire.	Mean of the Weights.
Copper,	4·54	7·302 089 561	7·267 916 135
	3·28	6·673 739 463	
	4·80	7·915 006 500	
	3·13	7·180 829 016	
Gold,	0·45	3·737 029 531	3·797 659 803
	0·46	3·858 290 076	
Platinum,	1·30	4·814 705 067	5·030 328 291
	1·17	5·002 548 676	
	1·19	5·273 731 130	
Silver,	1·10	5·134 832 974	5·102 864 252
	1·50	5·070 895 529	
Palladium,	1·34	6·581 140 502	7·407 916 947
	1·54	7·650 438 037	
	1·58	7·992 172 301	
Iron,	3·10	11·310 301 767	11·149 355 950
	3·10	11·237 545 433	
	3·20	10·900 220 650	

Although the experiments recorded in the preceding tables were made under very favorable conditions for uniformity, it is none the less true that they present considerable differences in the results; nevertheless, these differences are within such limits as to show with precision that the tenacity of the metals varies with the temperature to which they are subjected, and according to determinable laws.

In a theoretical point of view, the maximum tenacity obtained should be the nearest to the truth, for in the experiments there was nothing to increase the cohesion of the molecules of the metals, while on the contrary, many circumstances might diminish it; but in a practical point of view, the mean result must be adopted, for it has more chances to be correct in application.

The following table has been constructed according to this principle; and it contains, additionally, the tenacity of the metals on which I operated calculated for one square inch of cross section. This calculation permits, further, the comparison of the tenacities of the different metals with each other. [See page 44.]

There results from these experiments:

1. That the tenacity of each metal varies with the temperature.

2. That, generally, it decreases—but not without exception—as the temperature rises.

3. That for silver, it diminishes more rapidly than the temperature rises.

4. That for copper, gold, platinum and palladium, it diminishes less rapidly than the temperature rises.

5. That iron presents a particular case and a very remarkable one. At 212° Fahrenheit, its tenacity is less than at 32° Fahrenheit, but at 392° Fahrenheit it is greater than at 32°. M. Wertheim has likewise obtained an analogous result. The experiments, furthermore, have been repeated a sufficient number of times to leave no doubt in that respect.

If the tenacities be taken for ordinates, and the temperatures for abscissas, and the points thus obtained be joined by straight lines, there will appear by simple inspection of this graphic trace that, if the tenacity of the iron ought to be represented by a symmetrical curve, the minimum of tenacity would fall a little below 212° Fahrenheit; but should the variation in the tenacity of the metal be due to a new arrangement of its molecules, causing, as a consequence, a variation in the latent heat, then, by as much as that result is probable, should the minimum of tenacity be beyond 212° Fahrenheit, and the line which represents it ought to jut up suddenly and parallel to the ordinates.

Tenacity of the principal Malleable Metals at the Temperatures of 32°, 212°, and 392° Fahrenheit, in Wire of the Diameter and Cross Section experimentally found; and for one square inch of Cross Section as given by calculation.

Name of the Metal.	Diameter of the wire in fractions of an inch, at 60·8° Fahr.	Cross section of the wire in fractions of a square inch, at 60.8 Fahr.	Tenacity in pounds at			Tenacity in pounds per square inch of cross section at			
			32° Fahr.	212° Fahr.	392° Fahr.	32° Fahr.	212° Fahr.	392° Fahr.	
Gold,	0·016 240 455	0·000 207 152	5·613 260 877	4·645 381 252	3·858 290 076	27 097	22 425	18 625	Maximum.
			5·421 448 741	4·487 375 087	3·797 659 803	26 171	21 662	18 333	Minimum.
Platinum,	0·016 142 028	0·000 204 648	6·702 401 047	5·943 971 454	5·273 731 130	32 751	29 045	25 770	Maximum.
			6·585 549 976	5·613 260 877	5·030 328 291	32 180	27 429	24 580	Minimum.
Copper,	0·017 716 860	0·000 246 522	10·108 720 000	8·796 901 374	7·915 006 500	41 005	35 684	32 107	Maximum.
			10·015 018 666	8·725 798 601	7·267 916 135	40 625	35 395	29 482	Minimum.
Silver,	0·015 679 421	0·000 193 086	7·859 888 070	6·735 472 104	5·134 832 974	40 706	34 883	26 593	Maximum.
			7·779 047 706	6·388 777 182	5·102 864 252	40 288	33 088	26 428	Minimum.
Palladium,	0·015 649 893	0·000 192 362	10·119 743 686	9·001 941 932	7·992 172 301	52 608	46 797	41 547	Maximum.
			9·981 947 612	8·888 397 967	7·407 916 947	51 891	46 206	38 510	Minimum.
Iron,	0·006 889 890	0·000 372 834	11·125 103 843	10·659 904 297	11·310 301 767	298 393	285 915	303 360	Maximum.
			10·886 441 042	10·165 491 982	11·149 355 950	291 991	272 655	299 043	Minimum.

Further experiments are indispensable for solving this problem, which is one of great interest not only in a theoretical point of view, but also because it appertains to the most commonly used metal, and the one always employed in the construction of steam boilers.

THE MOON'S FIGURE AS OBTAINED IN THE STEREOSCOPE.

By Chas. J. Wister.

In a paper published some time since, in the "*Cornhill Magazine*," and republished, September last, in the "*Living Age*," entitled "*News from the Moon*," a singular argument, and to my mind a singularly fallacious one, is put forth in confirmation of the figure of the moon as deduced from the calculations of the continental astronomer, Gussew, of Wilna. The article referred to is without signature, but as the author alludes to his correspondence with Sir John Herschel, he no doubt speaks *ex cathedra*.

The figure of the moon should be, as proved by Newton, an ellipsoid, her shortest diameter being her polar one, her longest diameter that turned towards the earth, and her third diameter lying nearly east and west, a diameter intermediate to the other two. Newton further found that her shortest diameter would not differ more than sixty-two yards from her longest—an insignificant difference surely in a body whose mean diameter is about twenty-one hundred miles.

Gussew, however, comes in at this point with an assertion based upon measurements of De la Rue's photographic copies of the moon at the extremes of her librations; and upon ocular demonstration derived from viewing these different perspectives of the moon's image combined by the aid of the stereoscope, undertakes to subvert his great predecessor's theory, and to substitute one of his own, founded on this very unreliable testimony. He asserts not only that the moon is egg-shaped, its smaller end being turned earthward, but that the point of this colossal egg rises seventy miles above the mean level of its surface. Now it is to the proof of this as derived from stereoscopic evidence that I take exception for reasons hereinafter set forth.

The stereoscopic views of the moon are, as already stated, taken in the opposite stages of her librations, in order to obtain greater differences of perspective than would be obtained if taken in the ordinary way, where the separation of the two pictures corresponds with the average distance between the eyes of adults—four and a half inches; for this, it is evident, would give no more spheroidal appearance when viewed through stereoscopic glasses than is obtained by viewing her by unassisted vision, in which cases she appears as a disk only, and not as a sphere. With the same object—that of increasing the stereoscopic illusion (for illusion only it is) it is not uncommon for photographers, when taking stereoscopic views of distant scenery, to avail themselves of the same means—that of unnaturally increasing the base of operations—and thus effecting a much greater apparent separation of the various planes of distance than really exists. The effect of this is to distort the picture painfully, advancing the middle distance boldly into the foreground—similar points being combined by the stereoscope much nearer the eyes than if the pictures had been taken in the normal way—whilst the foreground is seen so near that one feels it in his power almost to reach it with his hand. Another and more objectionable feature of this exaggerated perspective effect is that all near objects are dwarfed; men become pigmies; imposing mansions are reduced to baby-houses, and lofty trees become insignificant bushes—the reason being that these objects, though seen at points much nearer the eye, subtend, nevertheless, the same visual angles as though seen at more distant points—points corresponding with their true position in the landscape—for the photographic representations of them are no larger, and therefore appearing nearer, and yet subtending no greater visual angles, the impression upon the mind is that of smaller objects. Every one, I think, who has viewed stereoscopic pictures of distant objects, combining middle distance and foreground, must have witnessed this distortion.

Now let us apply this principle of optics to De la Rue's exaggerated stereoscopic perspectives of the moon, and what is the result?

Sir William Herschel says, in illustration of the effect of stereoscopically combining images of our satellite taken at opposite stages of her librations, "it appears just as a giant might see it, the interval between whose eyes is equal to the distance between the place where the earth stood when one view was taken, and the place to which it would have been removed (the moon being regarded as fixed) to get the other." Now this would all be very well provided the pictures produced were for the use of giants formed after the pattern proposed; for they would see the stereoscopic image under exactly the same circumstances that they would see the moon herself in the natural way with their widely separated organs—no greater change being required in the direction of the optic axes in combining similar points of the two perspectives than is required in viewing corresponding points of the moon's surface by unassisted vision; but when these exaggerated perspectives are presented in a stereoscope to finite beings like ourselves, the effect is magical indeed. Then do near points of the moon protrude in a most alarming manner, threatening to punch us in the eyes, the whole presenting the appearance of an unusually elongated turkey's egg. Neither the modest sixty-two yards of the immortal Newton, nor the more pretentious seventy miles of Gussew would satisfy her claims now; nothing, indeed, less than several thousand miles would represent the difference between her longest and shortest diameters thus distorted.

Indeed, for a very pretty scientific toy, with which De la Rue has supplied us, this distortion of the moon's image is of little moment. The curious are, no doubt more pleased with it than if it appeared in its true proportions—for figures generally are more admired the less nearly they conform to nature's lines—but that men of science, even great men, should accept this delusive and distorted image as a basis for serious investigation of the figure of our satellite, conscious of the manner in which pictures producing this image are taken—and, though forwarned, should not be forarmed—passeth my understanding. It is but another instance of the too great avidity with which world renowned philosophers seize upon the most unreliable evidence from which to draw conclusions most important to science, thus shaking the faith of those who have hitherto looked upon them as infallible.

ON THE MECHANICAL PROPERTIES OF MATERIALS OF CONSTRUCTION.

And on Various Previously Unobserved Phenomena, Noticed during Experimental Researches with a New Testing Machine, with Autographic Registry.

[Read before the Am. Soc. Civil Engineers, April 4, 1874.]

By Prof. R. H. Thurston.

[Continued from Vol. LXVII, page 430]

Section II.

21. The manner in which this reduction of internal strain occurs, by continued stress at the limit of elasticity, as here observed, may be readily conceived.

When the metal is thus strained, many sets of molecules are placed in positions in which they exert a maximum effect tending to produce molecular changes which may equalize the originally irregular distribution of inter-molecular stresses. After a time, the change actually takes place by "flow," and the resisting power of the piece becomes increased, and its limit of elasticity raised, simply because its forces are now no longer divided, and may act together in resisting external forces. The diagram itself exhibits the best evidence of the occurrence of flow, but it is also shown by an inspection of the broken specimen, as in Figures 6, 7 and 11, of Section I.

It was at first suspected that an action had been detected in this phenomenon, similar to that by which the "portative force" of a magnet is increased by loading its keeper more and more heavily until it becomes "supersaturated." It is not impossible, perhaps not improbable, that the two cases are similar, in some respects, this behaviour of the cohesive force in the present example, aiding to produce the extraordinary increase of resisting power here observed.

A comparison of the ductility registered by samples variously treated lends some confirmation to the supposition, formerly expressed, that, in all cases, the resilience does not increase in the same proportion as the increase of mean resistance, as a consequence of sustained stress, and this, if a fact, may possibly be considered as corroborating the idea just suggested.*

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*Since the above was written, the *Journal of the Franklin Institute* has, in the issue for March, 1874, given an account of experiments made by Com'd'r Beardslee, U. S. N., during which metal strained beyond the elastic limit by tension, exhibited a gain of resistance at a position of earliest set, *i. e.*, an elevation of the elastic limit, from 23.075, to 26,100 pounds per square inch, 13.1 per cent., in seventeen hours. The material was bloom iron turned approximately to one-half square inch section.

A very important fact noted by the experimenter is that an apparent positive action was observed in the metal under strain by which the scale beam was actually thrown up by a force measuring 125 pounds. If this observation is not erroneous, or, if the action was not due to some accidental circumstance, we may have here a measure of the *intensifying effect* above described.

Commander Beardslee has communicated to the writer the experimental confirmation of the fact, deducible from the explanation here given, that this release of internal strain occurs to a nearly equal extent if the strained piece is simply laid aside for a similar interval after it has been given a set.

NOTE.—In further confirmation of the increase of resistance to strain, caused by permitting a metal to rest after the first application, I offer the following, taken at random from my test book: One link Pembroke iron made into form for service, 1 13-16, pulled first time to 185,000 lbs., whenit broke the proving chain; the next day it was pulled again until broken, standing the extraordinary strain of 262,200 lbs., other links from same bar having broken very uniformly at about 240,000 lbs.

From uniform bars of $1\frac{1}{8}$ inch chain iron (Pembroke), a number were left unbroken, after a day's testing, having broken shackles, end links, etc., at from 90 to

The discovery of this elevation of the elastic limit in all metals examined is also probably confirmatory of this idea.

If the explanation, just offered, of the apparent strengthening action of prolonged stress is correct, the conclusions of Vicat are not overthrown, although evidently not fully justified by his own experiments, and although the intervening forty years of engineering practice have not produced evidence which may be considered as confirmatory of them.

The same molecular movement, or flow, which rearranges the internal forces and relieves internal strain, may be a phase of that viscosity which Vicat supposed might in time permit rupture of metal subjected to stress nearly approaching its original ultimate resistance, the one action being a more immediate result than the other, and the latter producing its effect, even when cohesive force may have been actually intensified.

Should this prove to be the fact, it would seem allowable to conclude that the forces of polarity and cohesion are not identical. The cause of the apparent increase of strength of iron, with increase of temperature, is seen to be explained by this relief of internal strain, which occurs most readily at high temperatures.

The experiments of the writer have not indicated the possibility of continued flow, and, consequently of ultimate rupture, except under stress, increasing in intensity up to the full maximum resistance of the material.* They do not, therefore, confirm Vicat's deductions, and the inference would seem, on the contrary, to be—that structures of metal do not become weakened with age, except as injury occurs by corrosion, or by overloading. The experiments of Roebling† and his opinion, as expressed in his report on the Niagara Suspension Bridge, are apparently correct.

Kirkaldy, also, concludes that the additional time occupied in testing certain specimens of which he determined the elongation "had no injurious effect in lessening the amount of breaking strain."‡ An

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100,000 lbs. Of the links which were broken the first day, none went over 100,000 lbs. The next day the unbroken ones were submitted to pulls until broken, and now went under 100,000, and then ran up to 102, 106, 108, and in one link, on the sixth pull, to 114,200 lbs. L. A. Beardslee.

* Compare Kirkaldy—*Experiments on Wrought Iron and Steel*—pp. 62–69; also see the plates given by Styffe, exhibiting curves for tension.

† *Journal Franklin Institute*, 1860; Vol. XL, p. 360.

‡ *Experiments on Wrought Iron and Steel*, pp. 62, 83.

examination of his tables shows those bars which were longest under strain to have had highest average resistance.

22. Wertheim supposed that greater resistance was offered to rapidly, than to slowly, produced rupture; Kirkaldy concludes that the contrary is the case. Redtenbacher* and Weisbach† assume the law of resistance to be the same beyond the limit of elasticity as within it, and deduce formulas for resistance to shock which are widely inaccurate.

The experiments of the writer prove that, as had already been indicated by Kirkaldy (whose results, however, had been looked on by many of the profession with some suspicion), a lower resistance is offered as the stress is more rapidly applied. This conspires with *vis viva* to produce rupture.

This is seen at *w*, No. 101, Plate III, where a sudden increase of velocity produced a depression of the line, at the angle 110°, and it is exhibited in a much more marked degree in No. 118.

In the latter example, the strain was gradually applied until the point *a* was reached, when, with a suddenly applied force, a motion estimated at about one-tenth of a foot per second, was obtained and, immediately at *b*, the resistance fell off very considerably, the pencil dropping to *c*. Again resuming the slowest movement, about one hundredth of a foot or less per second, resistance rose again to *d*. A repetition of the rapid movement between *d* and b^1, was followed by a loss of resistance again from b^1 to c^1, and, as is seen by the diagram, this occurred whenever the experiment was repeated. At *k*, distortion by a very slow movement was resumed, and continued until the specimen broke. Here we have, probably, the first direct determination of this question, in which the effect of *vis viva* does not appear.

We may, therefore, conclude that the rapidity of action, in cases of shock, and where materials sustain live loads, is a very important element in the determination of their resisting power not only for the reason given already in paragraph 3 of this section, but because *the more rapidly the metal is ruptured, the less is its resistance to rupture.* This loss of resistance is about 15 per cent.‡ in No. 118.

The cause of this action we may presume to bear a close relation to that operating to produce the opposite phenomenon of the elevation of the elastic limit by prolonged stress, and it may probably be simply another illustration of the effect of internal strain.

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* *Der Maschinenbau*, Vol. I. † *Mechanics of Engineering*, etc

‡ Compare Kirkaldy, p. 83. where experiments, which are possibly affected by the action of *vis viva* indicate a very similar effect.

With a very slow distortion, the "flow" already described occurs, and but a small amount of internal strain may be produced, since, by the action noticed when left at rest, this strain relieves itself as rapidly as produced. A more rapid distortion produces internal strain more rapidly than relief can take place, and the more quickly it occurs, the less thoroughly can it be relieved, and the more is the total resistance of the piece reduced. Evidence confirmatory of this explanation is found in the fact that bodies most homogeneous as to strain exhibited the least of these effects.

It does not seem impossible that, at extremely high velocities, the most ductile substances may exhibit similar behavior, when fractured by shock, or by a suddenly applied force, to substances which are really comparatively brittle.

In the production of this effect, which has been frequently observed in the fracture of iron, although the cause has not been recognized, the inertia of the mass attacked and the actual depreciation of resisting power just observed, conspire to produce results which would seem quite inexplicable, except for the evidently great concentration of energy here referred to, which, in consequence of this conspiring of inertia and reduced resistance, brings the total effort upon a comparatively limited portion of the material, producing the short fracture with its granular surfaces, which is the well known characteristic of sudden rupture.

Any cause acting to produce increased density, as reduction of temperature, evidently must intensify this action of suddenly applied stress.

The liability of machinery and structures to injury by shock is thus greatly increased, and it is quite uncertain what is the proper factor of safety to adopt in cases in which the shocks are rapidly produced. This uncertainty must remain until further experiment shall be made the basis of a correct mathematical expression of the natural laws involved in the problem.

Meantime the precautions to be taken by the engineer are: To prevent the occurrence of shock as far as possible, and to use in parts exposed to shock, light and elastic members, composed of the most ductile materials available, giving them such forms as shall distribute the distortion as uniformly and as widely as possible.

23. The behavior of materials subjected to sudden strain is thus

seen to be so considerably modified by both internal and external conditions, which are themselves variable in character, that it may still prove quite difficult to obtain mathematical expressions for the laws governing them. It is not improbable, however, that an approximation, of sufficient accuracy for all cases which frequently arise in practice, may be obtained by a study and comparison of experimental results obtained, as above, by the method here adopted, and one which seems peculiarly adapted to the work.

A carefully conducted series of experiments giving quantitative results would be of great value. Without such a research no reliable knowledge can be obtained of the law of depreciation, and no useful formulas can be devised for use in calculation. The experiments made by the writer are not yet sufficiently numerous or precise to serve as data from which to deduce equations.

24. THE ELASTICITY OF THE METALS.—The examination of the "elasticity line" will be found to present some facts of interest.

It will be seen that, in every case, the line produced by the descent of the pencil is not precisely coincident with that formed by its rise. This is not due to the friction of the machine, as that would not cause the decided difference observable in the form of the curve. It may be partly due to the fact that the set produced is partly temporary.*

An attempt was made to determine its law by the following method:

A steam gauge having a recording apparatus, in which the paper was moved horizontally, at a uniform rate, by a well-constructed clock, was kindly furnished by the Messrs. Edson, of the New York Recording Gauge Co.

This was set up by the side of the machine, upon a stand on which could be clamped the test piece. The latter carried a light, long pencil holder, so arranged as to traverse the paper in a direction at right angles to that of the motion given it by the clock. An angular motion in the specimen of 0·05° would be readily observed. The specimen was given a degree of torsion of from 10° to 360°, in different cases, and was then rapidly transferred to the stand, where the restoration of form would record itself upon the moving paper, forming a curve of which the ordinates would represent the restoration of form, and the abscissas would be proportional to the time.

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* Morin, *Resistance des Materiaux*, p. 10.

In all cases observed, the restoration of form, by loss of temporary set, was so rapid as to have become completed before the specimen could be placed in the recording apparatus, and the record made a straight line invariably.

The conclusion which has finally been deduced from a study of the diagrams obtained is, that the peculiar feature here alluded to is a consequence of an internal molecular friction, the existence of which has already been long suspected by the writer, and probably by many other experimenters.

An illustration of a similar action probably occurs in the behavior of iron under magnetic action. Magnetization produced in bars of various qualities of iron and steel during important researches of Dr. Joule* and Prof. Tyndall,† proved this behavior to be common to all, when the change of form was produced, within a very minute range even, by magnetic force. Dr. Mayer has more recently‡ examined this peculiar form of molecular action with great skill and thoroughness. Its existence is undoubtedly well proven, and the lines, above referred to, on the strain-diagrams seem to exhibit its effect very clearly. Possibly the rise from *f* to *g*, No. 118, Plate III, is due to such friction.

25. The evident proof found, in the parallelism of all elasticity lines in each diagram, of the fact, first noted by some of the earliest experimenters in this field, that elasticity remains quite unimpaired up to the point at which rupture commences, has been already adverted to.

Coulomb describes a series of curious and instructive experiments which may assist in determining the molecular action occurring in these instances where great distortion and great permanent displacement of particles takes place without loss of elasticity.§

He found this to occur, not only with metal wires, but with threads of fine clay, 1–12 of an inch in diameter and 11 feet long, which could be twisted $5\frac{1}{2}$ turns repeatedly without set and without apparent loss of elasticity. Turning the thread through a wider range of torsion, it always returned but $5\frac{1}{2}$ revolutions, and in each new position of set exhibited the same elasticity as before.

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* *Philosophical Magazine*, 1874.

† *Researches on Diamagnetism*, etc., 1870.

‡ "*Effects of Magnetism in changing dimensions of iron and steel bars*," by A. M. Mayer, Ph. D.; Stevens' Institute of Technology, 1872. *American Journal of Science and Arts*, 1873.

§ *Lecture Notes on Physics*, Mayer; *Journal Franklin Institute*, 1868.

The explanation of this action, as illustrated by the strain diagrams of Plates II and III, and by Coulomb's experiments, is probably also to be found in the phenomenon of flow of solids. The restoration of cohesion, in bodies actually separated, exhibits the extent to which this action may proceed. Two freshly cut surfaces of lead when brought together with a moderate pressure cohere firmly; and plates of glass, laid one upon another, sometimes "seize" each other so firmly that they are cut and worked as one piece.* The welding of iron is another and a very familiar illustration of the same action. Cohesion may therefore be actually destroyed and renewed, and molecules may move among each other, changing completely their relative positions, without loss of either strength or elasticity.

The results of these experiments on metal are important as exhibiting the error of the opinion hitherto entertained by many physicists and engineers, among whom was the writer,† that straining metal might weaken it, even when rupture did not commence, and even where no condition of internal strain was induced. It has been here shown that elasticity remains unimpaired, and resistance continually increases up to the point at which incipient fracture takes place. No well proven exception to this law has been observed.

26. While comparing the inclination of the elasticity lines with the initial line, to determine the pressure and the amount of internal strain, it has been noticed that more or less strain seems almost invariably to exist, but that the amount, as indicated by the difference in inclination of the two lines, is not always as well shown by the greater or less curvature of the initial portion of the diagram. The probable reason would seem to be that this strain is not always uniformly distributed. Were the strain considerable and uniformly distributed, the initial line would be strongly convex toward the base line, and would have the parabolic form. Absence of strain is indicated by a straight line rising regularly to the elastic limit, or, in many cases where the elastic limit is very low, and when the material is inelastic and flows without tendency to recoil, concave toward the base, and parabolic. Irregularly distributed strain would modify the parabolic curve, and the amount of strain would determine the total curvature.

The initial and elasticity lines have, therefore, great interest as revealing important and otherwise unrecognizable properties of the material.

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* *Miller, Chemical Physics*, p. 67. † *Journal Franklin Institute.*

It has been remarked that the difference of inclination just referred to, proves the truth of the assertion of Hodgkinson that every load produces a set. It can now be readily seen why this should usually be the fact, and also that, although it is true, it does not necessarily indicate injury of the material.

Since, in its ordinary state, many sets of particles are usually in a condition of maximum strain, the slightest application of external force to the piece will destroy the existing equilibrium among these conflicting forces within the mass, producing a change of form, and either rupturing or producing a flow of those particles which are most strained, and thus causing a new condition of equilibrium, the piece returning only approximately to the original form when relieved. The greater or less the applied force, the greater or less the number of displaced particles, but it is only when the set becomes nearly proportional to the distortion that it assumes the character in which it is looked upon as a serious effect.

With perfectly homogeneous materials, free from internal strain, no such action would be noticed, and the earliest set would occur beyond the elastic limit, which limit is here considered to be attained when the set becomes proportional to the distortion.

27. The very minute range of distortion within the elastic limit is shown by the strain-diagrams very beautifully. This point is usually reached with the first 5° of torsion, and where internal strain has been eliminated it is frequently found within 2°, the corresponding extension being much less than ·0001.

Captain Rodman, who has made the most delicate determination yet published,* detects a set of 0·000,001,4 after an extension of 0·000,27 in a specimen of cast-iron, and the elastic limit, as here defined, is reached after an elongation of about 0·0003, the point not being however, very accurately determinable on account of the insensible change of rate, as already observed, in the strain-diagrams of cast-iron.

The immense magnification on the strain-diagrams, obtained with the torsion machine, of the elongation at the commencement of the curve, enables the behavior of the materials within this minute, yet most important, portion of the entire range to be perfectly represented and permits its examination in a most satisfactory manner.

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* *Experiments on Metals for Cannon, etc.* Rodman, pp. 157-167.

28. THE INFLUENCE OF VARIATIONS OF TEMPERATURE.—The effect upon the mechanical properties of metal of variations of temperature has long been a subject of debate, and one which has not even yet been satisfactorily settled by experiment.

A *priori* it would appear that, in a perfectly homogeneous material, entirely free from internal strain, change of temperature would produce an alteration of strength and of ductility which would both be the reverse, in direction, of the variation of temperature.

The forces acting to produce mechanical changes being, probably, cohesive force, on the one hand, resisting external forces tending to produce distortion or rupture, while the force produced by the energy of heat-motion conspires with external force to produce that distortion, and the molecules being, at every instant in equilibrium between the force of cohesion on the one side, and the sum of the other two forces mentioned, on the other, variations of form must ensue with every change in the relative magnitudes of these forces. A change of temperature produced by an increment of heat energy, it would appear, must produce a reduction of cohesion by separation of particles, and the opposite change must cause an increase of cohesion by their approximation. Increase of temperature, by reducing the range of action of cohesion by separating particles, and causing them to approach the limit of reach of cohesive force, would reduce ductility, and the opposite change of temperature would increase extensibility. The effect on resilience, the product of ductility and strength, would evidently be still more marked than the variation of its factors.

The peculiar behavior of zinc, and the often observed brittleness of iron, at low temperatures, have given cause for doubting the truth of the above statement, and until the phenomena accompanying variations in homogeneousness of structure and composition, and the introduction or removal of internal strain, have been very thoroughly investigated, it cannot be anticipated that the subject will become well understood. The character of polarity, that force of which the presence constitutes the distinguishing difference between solids and liquids, remains to be determined, and its determination may be expected to throw important light upon this subject.

Experiments of both physicists and engineers have failed, up to the present time, to give as much, and as precise information as is needed to determine satisfactorily what rules should govern the proportions of structures, whether carrying dead loads or subjected to shocks or blows, at any given temperature below the usual range, or even at the low temperatures to be met during every winter in the latitude of New York.

In a paper recently published* on "Molecular Changes produced by Variations of Temperature," the writer gave the results of a careful investigation of the experimental work previously done, by both philosophers and engineers, in researches bearing upon this important question.

29. The conclusions, as there reached, were the following:—

1. That the number and the nature of those molecular forces which determine the physical condition of matter are not yet fully ascertained, but that these forces manifest themselves in, at least, three distinct modes of action, and, as thus exhibited, they are known as repulsion, cohesion, and polarity.

2. That the force of repulsion is, apparently, heat, motion, or some closely related phase of energy. That the force of cohesion bears some resemblance to that of gravitation, but seems not to be identical with the latter, and that the force of molecular polarity, which determines the molecular relations of position, seems to bear some distant relation to that of magnetic polarity.

3. That the law which governs the variations in intensity of these forces with changes of intermolecular distances, is undetermined, and that it has not been expressed by any mathematical formula, except approximately and for a limited range.

4. That the magnitudes of the intermolecular spaces, and consequently, the volume of any mass, are variable with changes in the relative magnitudes of the forces of cohesion and repulsion.

5. That the resistance offered to change of form is determined by the relations in intensity of the forces of polarity and those forces which determine intermolecular distances.

6. That, at the "absolute zero" (— 461·2° Fahr.), cohesion, and consequently the strength of the material has, probably, its maximum value, heat-energy having disappeared.

7. That, at very high temperatures, heat-energy exerts a separating force upon particles, which entirely overcomes the other forces, and matter, assuming the gaseous state, requires the action of extraneous forces to preserve its volume unchanged.

8. That, at intermediate points, matter, in either the solid or the liquid states, exhibits a definite degree of separation of molecules

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* *Iron Age*, June, 1873; *Van Nostrand's Magazine*, July, 1873; *Jour. Frank. Inst.* 1873; *London Jour.*, Jan., 1874. Also in pamphlet, p. 29. D. Van Nostrand.

which is determined by the intensity of the repulsion due to heat-motion, a position of equilibrium being assumed, which, with the same substance, is invariable for the same temperature. The application of some kind of force is required to disturb this equilibrium and to produce change of volume. The amount of this force is determined, for any given extent of disturbance, by the maximum value of cohesion for the substance and the quantity of heat which has been required to raise it from the absolute zero of temperature.

The sum of the applied force, and the force consequent upon the presence of heat-motion, must exceed cohesive force to produce dilatation, while this cohesive force, added to externally applied force, must exceed the force of repulsion to produce diminution of volume.

9. That the distinction between the solid and liquid states of matter seems due to the action, in the former, of the force of polarity, which gives stability of form, while, in the latter, this force is extremely feeble, disappearing altogether when the boundary line between the liquid and gaseous states is reached.

That combined stability and elasticity of volume may be produced by the equilibrium of attractive and repulsive forces, but that stability and elasticity of form demand the coexistence of cohesion and polarity.

10. That the general effect of increase or decrease of temperature is, with solid bodies, to decrease or increase their power of resistance to rupture, or to change of form, and their capability of sustaining "dead" loads.

11. That the general effect of change of temperature is to produce change of ductility, and, consequently, change of resilience, or power of resisting shocks and of carrying "live loads." This change is usually opposite in direction and greater in degree than the variation simultaneously occurring in tenacity.

12. That marked exceptions to this general law have been noted, but that it seems invariably the fact that, wherever an exception is observed in the influence upon tenacity, an exception may also be detected in the effect upon resilience. Causes which produce increase of strength seem also to produce a simultaneous decrease of ductility, and *vice versa*.

13. That experiments upon copper, so far as they have been carried, indicate that, (as to tenacity), the general law holds good with that metal.

14. That iron exhibits marked deviations from the law between or-

dinary temperatures and a point somewhere between 500° and 600° Fahr., the strength increasing between these limits to the extent of about 15 per cent. with good iron. The variation becomes more marked and the results more irregular as the metal is more impure.

15. That above 600° F. and below 70°, the general law holds good for iron, its tenacity increasing with diminishing temperature below the latter point, at the rate of from 0·02 to 0·03 per cent. for each degree Fahrenheit, while its resilience decreases in a higher but not well determined ratio for good iron, and to the extent of reduction to one-third its ordinary value, or less, at 10° F. when cold-short, and, in the latter case, the set may be less than one-fourth that noted at a temperature of 84° Fahr.

16. That the viscosity, ductility and resilience of metals are determined by identical conditions, and that the fracture of iron at low temperatures, has, accordingly, been found to be characteristic of a brittle material, while at the higher temperatures, it exhibits the appearance peculiar to ductile and somewhat viscous substances. The metal breaks in the first case, with slight permanent set and a short granular fracture, and in the latter with frequently a considerable set and a form of fracture indicating great ductility. The variation in the behavior of iron, as it approaches a welding heat, illustrates the latter condition in the most complete manner.

17. That the precise action of the elements with which iron is liable to be contaminated, and the extent to which they modify its behavior under varying temperature, remain to be fully investigated, but that the presence of phosphorus, and of other substances producing "cold shortness," exaggerates to a great degree, the effects of low temperature in producing loss of toughness and resilience.

18. That the modifications of the general law with other metals than iron and copper, and in the case of alloys, have not been studied, and are entirely unknown.

19. That these conclusions are sustained by experiments of both physicists and engineers.

"The practical result of the whole investigation is that iron and copper, and probably other metals, do not lose their power of sustaining 'dead' loads at low temperatures, but that they do lose to a very serious extent their power of sustaining shocks or of resisting sharp blows, and that the factors of safety in structures, need not to be increased in the former case, where exposure to severe cold is apprehended, but that machinery, rails, and other constructions which are to resist shocks, should have larger factors of safety, and should be most carefully protected, if possible, from extreme temperatures."

30. The conclusions above given were deduced from the physical investigations of Boscovich, Coulomb, Henry, Powell, Cagniard de la Tour, Andrews, Faraday, Wartmann ,Robinson, Gaudin, Thompson, Rankine and others, and from the more purely technical researches of Professors Johnson and Norton, Fairbairn, Kirkaldy, Brockbank, Joule, Spence, Styffe and Sandberg.

An apparent discrepancy of results from which some experiments seemed to indicate weakness, and others strength of metals as a consequence of reduced temperature, was explained by the fact that those which seemed to prove the first conclusion, were cases in which the metal was tested by blows, and those proving the reverse were tests made by steady strain. The deduction (11), made above, that the result of change of temperature, by producing changes of ductility, which were the reverse of those produced in tenacity, and that the same bar might thus exhibit a higher resistance to static stress while less capable of resisting shock, explained the seeming contradiction.

31. It was evident that, to determine satisfactorily the real effect of changes of temperature, it was necessary to obtain a series of experimental determinations of the simultaneous action of such variations upon both strength and resilience. Such experiments could readily be made by the method here pursued, and a considerable number of observations are represented by strain-diagrams on plate III.

In these experiments, the machine and the test pieces were placed in the open air, where, changing in temperature with the atmospheric changes, no error could arise by transfer of heat during the experiments. The machine and specimens submitted to test were always of the same temperature.

The mildness of the past winter has precluded the determination of the behavior of iron at temperatures very far below the freezing point, the lowest reached being 10° Fahr.

This is the more to be regretted since, as will be seen, there exists a possible change of law near the Fahrenheit zero, and it is extremely important to ascertain whether this indication of an anomaly arises from irregularity in the quality of specimens, nominally of the same grade, or whether it is a real variation of the effect of change of temperature.

As no previously made experiments combine, in the manner here presented, the various effects of heat upon the mechanical properties of the metals, the results obtained are given as a beginning, and the conclusions which are deduced from them are given as merely probable, while it is to be hoped that other members of the profession, who may be so situated that they can readily continue the work at points in the north and north-west where a temperature far below zero is reached, will make more complete and instructive researches during succeeding winters.

It is apparently quite impossible to avoid error if the attempt is made to experiment with specimens cooled down by freezing mixtures, and the writer would only feel justified in presenting the results of out-of-door work.

32. Referring to Plate III, the strain-diagrams of the best, and of medium tool steel, of German and double shear, of the several grades of iron and of copper and bronze are given, for temperatures from 70° down to 10° Fahr. A diagram is also given in which the horizontal scale of the plate is taken to represent absolute temperatures on a one-fourth scale, and at ordinates representing respectively 10°, 18°, 25° and 70°, the resistances of the several specimens are laid off, and dotted lines connecting them indicate the rate of variation of strength with temperature.

It will be seen that with the single exception of a scrap gray cast iron, presumably unusually impure (Nos. 25, 26), the effect seems invariably to have been a simultaneous increase of both strength and ductility with decrease of temperature to 18° and usually to 10° from 70° Fahr. In the case of the cast-iron, the increase of tenacity and reduction of ductility at the lower temperature are equally well exhibited, and the result is a slight decrease of resilience.

It will be noticed that the general trend of the lines in the diagram prepared for comparison of results, is very evidently towards a point on the scale (250°), corresponding to a temperature of 1000° above the absolute zero, at which point were the diminutions proportioned to temperature, the metals would lose all cohesion. Since, however, the law as determined approximately by the Committee of the Franklin Institute, is expressed by a parabolic equation, the fact that their melting points are nearer 3000° or perhaps 4000° Fahr. above the absolute zero, does not conflict with the results of experiment.

33. Comparing the several specimens of "good cast-steel," it is found that the four (Nos. 46, 47, 49, 50), whose strain-diagrams are

given, evidently differ nearly as much in their individual properties as in their alteration by temperature. The two pieces tested at 70° Fahr. give a mean of strength, ductility and resilience, which is less than either of the other specimens. The strongest piece was broken at 18° while that tested at 10° is very nearly its equal in that respect, and is more than 10 per cent. better in extensibility and nearly ten per cent. superior in resilience. The difference between the specimens tried at 10° and 70° (average of the two) is about 15 per cent. in ductility and resilience, and rather more than 5 per cent in tenacity. The piece tested at 10° has a limit of elasticity exceeding that of the specimens tested at 70° in about the same proportion.

The double shear steels are irregular, as would be expected from their method of production, but the greatest ductility is shown by the specimen tested at 25° F., and the greatest tenacity by that broken at 25° also. The weakest is that tested at 70°, its loss of strength, ductility and resilience being very striking. The position of the elastic limit varied with that of the ultimate strength. "German" (English) steel exhibits greatest strength at 18° (No. 60), greatest ductility at 70° (No. 58) and greatest resilience at 25° (No..25).

"Medium crucible" steel seems strongest at 18° Fahr., most ductile and equally resilient at 25°, and weakest, least ductile and least resilient at 70°. Nos. 78, 54, 70 are their strain-diagrams.

Swedish irons (No. 99 and 100) were tried at 25° and 70°, and the result is again that the greatest resistance and greatest extensibility occur at the lowest temperature, the difference here amounting to something less than 10 per cent. at the elastic limit and about one-half as much at the maximum.

A piece of common iron was selected by the blacksmith from his stock as "the worst specimen of cold short iron in the shop." The two specimens, Nos. 130 and 132, were taken from the bar and tested at 10° and 70° Fahr. respectively, with a result which is unexpectedly similar to those already given in the variation of ultimate strength, ductility and resilience. The increase of strength at the lower temperature is apparently nearly 15 per cent. the increase of ductility about the same, and the increase of resilience 30 per cent. At the elastic limit this is reversed, however, the specimen tested at 70° showing the highest elastic resistance. That broken at 10° exhibits a very considerable amount of internal strain, to the presence of which may be attributed the exceptional behavior of these pieces.

A similar difference but opposite in direction and in less amount is noticeable in the Swedish irons, Nos. 99 and 100.

Copper, Nos. 133 and 134, and bronze, Nos. 137, 138, both show a considerably greater strength at 10° than at 70° and a slightly improved ductility. The increase of tenacity and resilience amounts to 20 per cent. and 30 per cent. respectively, the ratio being slightly greater at the limit of elasticity.

Cast-iron exhibits the most striking increase of tenacity, the ratio of increase being above 30 per cent. and in ductility having a mean value of 50 per cent. One specimen, No. 25 *C*, has a serious defect of internal strain, but eliminating that by cutting off the sharply curved lower portion of the line, it would coincide very exactly with the companion specimen, No. 25 *D*, broken at the same temperature, 25°.

34. It would seem, after a study of these experiments and after a comparison with those described by other experimenters, that, although a considerable irregularity, due to differences in material nominally of identical character, tends to obscure them, that we may feel some confidence in drawing the following conclusions in modification and extension of those already given in article 29:

20. That, with pure, well-worked metals, the principle enunciated in article 29 is fully illustrated, and a decrease of temperature is accompanied by increase of strength, ductility and resilience.

21. That materials which are impure and irregular in character may exhibit exceptions to, and even reversals of, that principle in changes of ductility and, while increasing in power of resisting simple stress, may lose their power of resisting shock, by a diminution of temperature.

We may hence feel confidence that, with really good iron or steel, we are not exposed to seriously increased danger of failure of structures at such low temperatures as frequently occur in this latitude.

There is no reason to believe that the familiar effect of phosphorus in "cold-shortening" iron and steel, when cold, has its maximum effect at ordinary temperatures. The experiments of Sandberg would seem to prove this effect to be intensified continually with decrease of temperature.

35. Since the above research was concluded, the writer has become indebted to the thoughtful kindness of Mr. Chas. Francis Adams, Jr., for reports, one of which is that of the Mass. R. R. Commissioners for 1874 containing (page 144, *et seq.*), the result of an investigation of the cause of rail breakage on a considerable number of

railroads in the United States and Canada. The conclusions given are that "cold does not make iron or steel brittle, or unreliable, for mechanical purposes," and that "it was not the rule that the most breakages occur on the coldest days." The introduction of steel, in place of iron rails has caused an almost complete cessation of the breakage of rails (p. 150).

The deduction which would seem proper in comparing these latter statements with the work of Sandberg would seem to be, simply, that the latter experimented with cold-short rails. The same conclusion is given in Sandberg's own statement of the difference between Welsh and French metal.*

36. We still require, to give us reliable information regarding exceptional cases, a series of experiments to determine the action of excessively low temperature, and whether the apparent change of law near the Fahrenheit zero is a natural or a artificial phenomenon. We need to learn precisely the effects of sulphur, phosphorus, and silicon at extremely low temperatures. We need, also, and especially, to learn by experiment whether extremely low temperatures occuring during our winters, produce a serious effect upon iron and steel by the introduction of internal strain as the material decreases in volume and increases in density.

The uncertainty still existing as to the extent to which increased density at low temperatures and reduction of tenacity under sudden strains at all temperatures—phenomena which have been revealed but not measured during the investigations here described—will be recognized by every member of our profession as one which it is exceedingly important to remove. It is hoped that it may not long remain, for it is evident that, although perhaps improbable, it is not impossible that, notwithstanding the increase of both tenacity and ductility by reduction of temperature, these causes may still conspire to produce increased tendency to yield before shock at some unknown low temperature.

37. The peculiarities of fracture, which have been alluded to, are exhibited in the accompanying Plate.

Figures 15 and 16 exhibit the behaviour of a bar of iron made at Catasauqua, Pennsylvania, as broken by Mr. Oliver Williams, at 70°, and again at 20° Fahr. It is selected from among the specimens in the cabinet of the Stevens Institute of Technology. The fracture at 70° (Figure 15) has the fibrous fracture and all the characteristics of

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*P. 157, conclusion 3; p. 158, line 4; p. 32, Nos. 21, 24.

Fig. 15

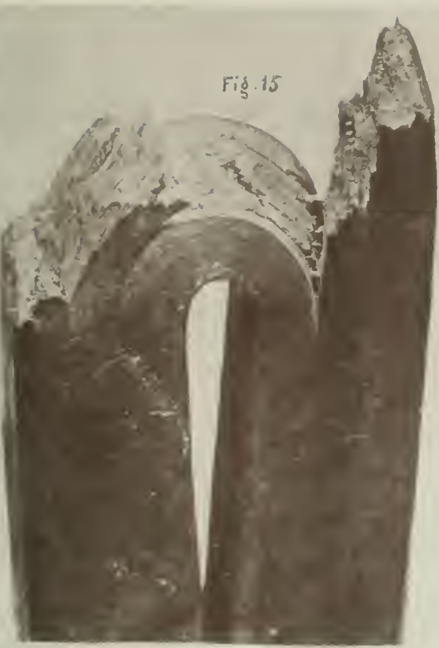


Fig. 16.

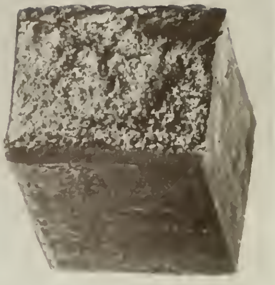


Fig. 17.

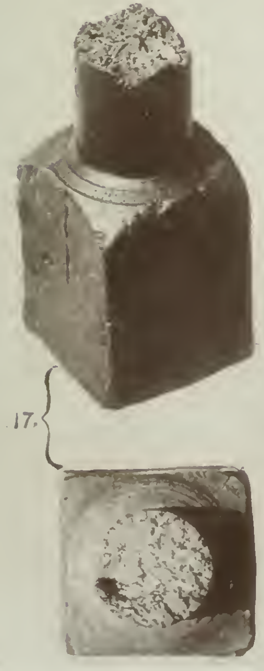
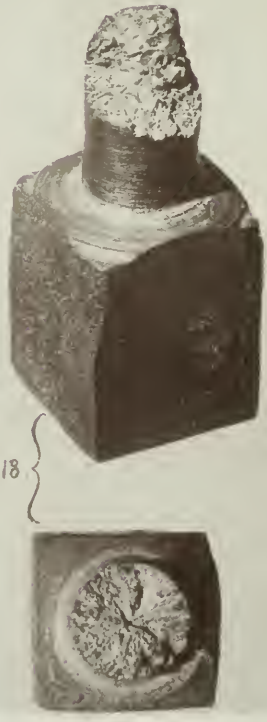


Fig 18.



what is generally considered a tough and ductile iron. That at 20° (Figure 16) resembles the break produced by a quick blow in good iron, or by any treatment at ordinary temperatures of a cold short iron. Were the conditions stated not known, it would be supposed that irons like Nos. 1 and 16, Figures 5 and 6, were combined in a single bar.

Figures 18 and 17 illustrate strikingly the difference between the specimens of copper, Nos. 87 and 133, which have been already described and of which the strain-diagram of the one is shown in Plate II, and of the other in Plate III. No. 87 was cast in green sand, and broken at 70° F., while the other was made from the same ingot, but cast in dry sand and broken at 10° Fahr.

The first is unsound in structure in consequence of the dampness of the mould and exhibits a peculiar radiated texture which is probably due to the same cause. The second is distinguished by its compact homogeneous structure probably due to the freedom of the mould from vapor and gases. It presents a beautiful crystalline fracture which is probably due partially, if not principally, to the low temperature at which it was broken.

These fractures are extremely interesting from the strongly typical features which they exhibit as characteristic of the peculiar conditions under which they were produced.

RESUME.

37. *En resume*, a review of this investigation of the nature of, and the influences affecting, the distortion and rupture of metals, it would seem allowable to accept, as extremely probable, the following

GENERAL CONCLUSIONS:

1. That accurate strain-diagrams, in which the behavior of the material, as distortion progresses, and especially about the elastic limit, afford a means of acquiring valuable information respecting the strength, elasticity, homogeneousness, ductility, and resilience of materials, and of tracing the modifications induced by variations of treatment and of composition

2. That internal strain plays a most important part in determining the behavior of materials strained by either static or dynamic stress.

3. That the time, during which applied stress acts, is an important element in determining its effect, not only as an element which modifies the effect of the *vis viva* of the attacking force and the action of

inertia of the piece attacked, but, also, as modifying seriously the conditions of production and relief of internal strain by even simple stresses.

4. That with good materials, cold does not produce injury, but actually improves their power of resisting stress and increases their resilience.

6. That the influence of impurities, of various methods of manufacture, of changes of density with temperature, and of the causes which produce a concentration of the action of rapidly produced distortion and of quick blows, are subjects which still require careful investigation.

7. That experiment confirms the theory as to the behavior of materials, homogeneous in composition, structure, and strain, as expressed *a priori* in 27, and hence a probable deduction that the force of molecular repulsion is heat motion.

SECOND CHEMICAL AND SANITARY REPORT UPON THE WATER SUPPLY OF THE CITIES OF NEWARK AND JERSEY CITY.

By Professor Henry Wurtz.

(Corrected and prepared for this Journal by the Author.)

[Continued from Vol. LXVII, page 436.]

5. *The Rockaway River.*—This stream runs through three towns of some size, Dover, Rockaway and Boonton. A smaller place also, Denville, imparts its drainage. Beginning with Boonton, I do not know whether the canal receives, on the level below the Boonton plane, any of the drainage of lower Boonton, but if so, this can easily be directed into the lower Rockaway. The main difficulty appears to be above Boonton, at Powerville, where the canal crosses and coalesces with the stream, the latter being brought up to the level of the former by the dam at that place. Thus the canal is made to partake of such contaminations as are brought down from the towns and population of the valley above. Whether by extinguishing the Powerville water-rights, and removing the dam, the two could be separated at this point, and the river conducted under the canal, is a question for the engineers to decide. The stream between Powerville and Dover, when observed during July, was seen to be opalescent and particularly offensive to the smell and taste, but during September it was perfectly limpid, inodorous and tasteless.

The result of the analysis of the Passaic Falls should teach us, however, not to trust too much to such external appearances. Inquiry in Dover elicited the fact that the citizens who occupy the thickly-settled river bottom are greatly dissatisfied with their *wells*, attributing much sickness to bad water. A few words on this head will not be out of place. It may be asserted that the wells, in a river valley filled with porous material, belong to the river itself, and partake of its current. The stream frequently—particularly in a dry season—will run more underground than on the surface; which is proved by the familiar fact that it will often disappear for distances more or less great, leaving the channel dry, and re-appear again in the channel below with its regular current. It is plain, when we consider this, that all drainage, all liquids of every kind from privies, open sewers, rain, etc., that soak into such a soil, become at once part of the flowing subterranean stream, and will flow *through the wells* themselves. The only variation in effect from the throwing of such effete liquids directly into the stream, is that in the latter case they have some chance of being consumed and rendered innoxious by oxygen, fish and vegetation, but, in the other case, little or none. These simple facts might, could and should, be taught to children in schools. Increase of population throughout country towns and villages will, probably, in time, cause the iron hand of necessity to be felt, and lead to increase of knowledge in these matters.

It is presumed that the canal, when passing Dover, can easily be kept separate from the Rockaway, and that such water as may be taken in from the stream may be derived from above that town, where the Rockaway is, unmistakeably, a pure mountain stream, coming down in two branches from wild and almost unsettled districts —one from the Longwood Valley, and the other from Denmark Valley and Green Lake, a lake which is the highest water in the State (1,044 feet above tide, or 130 feet higher than Lake Hopatcong). No sample was secured from this upper Rockaway, as it was assumed that it would be identical with the water of Lake Hopatcong, with whose tributaries some of its own interlace. This is now a subject of regret, as the Hopatcong water was found, by the analysis, to possess a certain peculiarity, as set forth below.

6. *Lake Hopatcong.*—As before stated, the visit to Lake Hopatcong was made upon a day which had been preceded (the night before) by a tremendous rain, which raised the level of the lake two inches, according to the statement of the lock-keeper at the feeder.

It was, therefore, thought interesting to take, in addition to the sample from the gate by the lock into the feeder, another sample from the margin of the lake, to determine the effect of the wash from the soil of the surrounding country. It will be observed—(No. 6), that this maginal water had a very different composition from that of the bosom of the Lake.

With regard to the latter, it may be interesting to compare the total solid contents with that of a few other lakes:

Lake Hopatcong,	1.79
Bala Lake, Wales,	1.63
Loch Katrine, (supplies Glasgow)	1.63
Norwich, Conn., Reservoir,	1.84
Cochituate Lake,	3.11
Lough Valley, Ireland, (supplies Dublin)	3.11
Croton Lake,	4.78
Geneva Lake, Switzerland,	8.87
Lake Ontario,	6.01
Lake Erie,	6.49
Lake Michigan,	6.68

[The analysis of Bala Lake, in Wales, here quoted from, was made by Frankland and Odling. Another analyst, R. H. Smith (possibly at a different season) obtained a very different result—2.65 grains per U. S. Gallon; and of this latter no less than 0.589 was chlorine—more than five times that in Lake Hopatcong. The Rhine, at Basle, in Switzerland, fed by the drainage of the Alps and the melting glaciers, while containing 9.88 grains of total dissolved matters per U. S. Gallon, has but 0.087 of chlorine. This is the purest natural water, so far as chlorine is concerned, that I have ever heard of. It will be seen that Hopatcong approaches it—containing but 0.014 grain more per gallon.]

These few examples are sufficient to show that this water is among the purest of lake waters. But still, on examining the figures of the analysis, a strange anomaly appears. I refer to the existence of *nitrates* in this mountain lake, in what may be called a large proportion. Of the fact there can be no shadow of doubt. The figures given are the mean of three well-concurrent analyses on three separate portions of the sample, collected by myself and sealed up in a chemically clean glass-stoppered bottle, and never opened until the analyses were begun. The presence and origin of these nitrates in Lake Hopatcong are mysteries to me at present. The only supposition I can make is that they exist in the water in the form of what are called nitro-humates, derived from peaty or decomposing *vegetable* matter. This is totally at war with the passage from Frankland, quoted on a previous page. It is to be borne in mind that, however produced, these nitrates are perfectly innocuous, and, in such minute quantities indeed, perfectly inert. The idea of their derivation from animal matter (unless from *dead fish*—an inadmissible idea) seems preposterous, and the possibility of drainage contamination in this lake, even if a supposable case, is negatived by the other figures obtained (See columns 9, 10, 11, and 12, of Table I.)

I observe that in an analysis of Loch Katrine, cited by Wanklyn and Chapman, the nitrogen existing as nitrates is given at 0·00031 milligramme per litre, equal to 0·06 grain of nitric acid per U. S. gallon. This is but one-sixth that in Hopatcong, but shows, nevertheless, that a mountain lake *may* contain nitrates. In any case the nitrate test is proved, in the case of mountain lakes and streams, in this country at least, to be of no use as *positive* evidence of sewage contamination, though *negatively* it may still be of value.

I have already stated, generally, the view to which my field and laboratory work jointly have impelled me, regarding a gravity low-service supply for your two cities, for the low-lying portions, where the main supply for business, manufacturing and steam purposes—as well as for fires, is required. I shall now say, that both Science and Nature appear to me to point clearly—as the source of a *high-service* supply of water from the hills, among the purest in the world, for drinking, washing and cooking uses, sufficient for all time, for Bergen Hill and the higher parts of Newark—to the elevated district comprising the united water-sheds of Lake Hopatcong and the upper Rockaway, above Dover. I have carefully marked out and measured the joint area of these two water-sheds. It forms a somewhat regular oblong parallelogram, twelve miles by six, or seventy-two square miles, which would give an average daily supply, the year round, of fully eighty million gallons. One month's flow, or less, during seasons of flood, would fill a reservoir as large as the new and huge Croton reservoir at Boyd's Corners, which might be located somewhere among the hills about Boonton or Montville, and to which the Hopatcong water and the Rockaway, above Dover, could be conducted through the canal. The piping required to take the water from such a reservoir to Belleville would be about sixteen miles in length, as the crow flies.

7. *The Croton Water.*—The Croton and its branches rise from and flow through a country identical in geological character with that traversed by the Rockaway, Pequannock and Ramapo, but it nevertheless receives the drainage from all the towns for twenty-five miles along the Harlem Railroad, besides a good many other settlements and farming districts scattered throughout its water-shed. I was led, therefore, to anticipate some interest from a few comparative, though partial tests, of samples from the New York hydrants. The results (Nos. 14 and 15) appear to show that our water of the Lower Passaic, even with all *its* contaminations, does not *as yet* suffer much in a comparison with the Croton. I would call attention particularly to the comparative chlorine tests.

Still, it is evident we have it within our power to improve *very greatly* on this, and it is to be borne in mind that *purity of water-supply* has already been—and in the future is to be, to a far greater extent—a paramount element of prosperity in a city. Those who conduce to progress in this respect, are eminently entitled to be enrolled among the benefactors of their community. If we are wise, we will take time by the forelock, and not wait for the Rider on the Pale Horse to come and *drive* us to our duty with some terrible death-dealing scourge.

8. *Pollution of Town Wells and Pumps.*—The members of your Honorable Commission are doubtless all familiar with much of the literature of this topic. I shall not go over, therefore, the well-known historical facts which are now so abundantly on record, and which show that epidemic diseases have been on numerous occasions propagated throughout whole communities by the water from a well or pump that had become contaminated by drainage. I might, however, cite here one case that has occurred in the United States within the last month. It was reported but a few weeks since from Davenport, Iowa, where nineteen deaths from cholera (or what passed for it) had occurred at the time within two days, that "nearly all of the cases may be traced to the suicidal use of water from the wells below the bluffs, which are little else than reservoirs of poison from sewage."

My attention was called to this subject in a conversation with his Honor Mayor Ricord, who stated that more than one quarter of the inhabitants of Newark still used well-water.* Knowing from the character of the soil in Newark, chiefly porous fluviatile sands and glacial drift, that this must be very unsafe, I requested Mr. Bailey to designate two or three of the public pumps most resorted to, that I might make some examinations. He indicated three, from which were obtained the samples whose contents are specified in Table I (Nos. 18, 19 and 20). Without occupying space with minute discussion, I shall only direct attention to the amount of common salt in Nos. 18 and 19 (column 12), about five grains to the gallon, of an ingredient which cannot be traced to any other source than infiltration of urine, of man or beast, or both. No. 20 is not so bad. It appears to me that strict prudence should prompt the closing of wells Nos. 18 and 19, and of all others that may be found to be receptacles of ooze and soakage from the contaminated soil under the city.

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* I am informed that this is the case also in Paterson, where similar dangers must be constantly impending—in view of the similar formations underlying that city—even to an extent more marked than at Newark.

9. *Brief Remarks on Sewage-Pollution of Rivers.*—This is also a subject that has been so much bewritten, that it may not be advisable for me to expend much space upon it.

The class of scientists who study microscopic fungi, mycologists (in common with many distinguished scientific physicians), are now settling down to the belief that most epidemic and epizootic diseases are accompanied (as *causes*, not merely as effects) by certain fungoid growths; in other words, that these diseases are produced by vegetable parasites. When these fungi take root in animal tissues, they develop into abnormal and monstrous forms, which have not been recognized until lately; but it is now known that the spores discharged (by millions of millions, it may be) with the excreta, when cultivated *outside* the body, come back again to their normal forms, and the fungi are recognizable. Thus, in common dysentery and cholera morbus, the spores, when replanted, produce a common fungoid parasite *wheat*, while during the fearful Asiatic cholera the spores produce a parasite of the East Indian *rice-plant.* These facts (if they must be admitted as such, which seems inevitable) are suggestive with regard to sewage contamination of rivers. One case of cholera brought to Paterson, or any one of the towns lying on the upper Passaic, might fill the whole river with the living seeds of the pestilence. A like propagation would take place from Newark throughout Jersey City and Hoboken, and even throughout Newark itself! I am aware that these are appalling considerations, and may be rejected by some as contingencies too remote and dreadful to be possible; but human experience, alas, will not countenance any such puerile view as this. We must stare these horrors sternly in the face, bring all our science to bear, and study prevention, rather than wait till called upon to endure the evil when it shall have passed beyond our cure.

Conclusions.—1. In addition to the rapid agencies of self-purification and nitrification, by oxidation, that were shown by the analyses of last winter to act in the Passaic water, the analyses of the past summer indicate, during the latter season, additional powerful agencies in the enormous amount of vegetable and animal life inhabiting this water, which co-operate in consuming the effete matter with surprising rapidity.

2. These last two agencies are unreliable, and may at any time fail us. It is probable that the limit is even now about reached, at which the excess of material for the nourishment of these beings—or rather the inevitably poisonous products of the putrefaction of this excess—will engender all at once some deadly epidemic, or rather *epi-ichthyic* disease, which will destroy the fish, as is well known to have always resulted, sooner or later, in similar cases.

3. The analysis of Jersey City reservoir water of August 9th shows that even now there are times when these consuming agencies fail to come fully up to the mark, so that the average of putrefiable matter in the water, as distributed to consumers, rises to a proportion that should cause deep disquietude.

4. The large indications of matter of animal origin in solution at low-tide at the Newark pumps at Belleville, overthrows the plan brought forward in the Chemical Report of last March, that the water be conveyed to the pumps from a point higher up the river.

5. The water above the falls at Paterson does not present, at least in summer, the purity that appears desirable in a water-supply to be selected and adopted for all time, especially when it is remembered that the main Passaic receives a large and constantly increasing amount of drainage from towns, country and factories, as well as much swamp-ooze.

6. The Morris Canal, on the long level, above Paterson, extending to Bloomfield, much excels in purity the water above the falls at Paterson (see Table VI), containing but about one-half the volatile matter, nitrates, animal matter and chlorine.

7. Were the incessant surging against the banks of the canal, by passing boats, to be stopped, its water would quickly assume a limpidity or clearness equal to that of the river above the falls.

8. The canal feeder at Pompton Plains, which is capable of draining more than one-third of the whole Passaic water-shed—and which

comes down from a country very little cultivated and sparsely settled —brings water which is far beyond that of Passaic Falls in purity; the amount of total solids in the feeder to that in the upper Passaic being as 1 to 1·38, the amount of nitrates as 1 to 2·4 and the amount of chlorine as 1 to 2·17.

9. Were the main canal, above the Pompton feeder, protected from contamination by the towns and villages along the valley of the Rockaway, and its influx of water confined to the Hopatcong feeder and the Rockaway above Dover, it is probable, indeed reasonably certain, that its water would acquire a purity even much greater than that of the Pompton feeder.

10. Lake Hopatcong is scarce surpassed in purity by any mountain lake whose analysis is on record, being very closely equal to the celebrated Loch Katrine that supplies Glasgow.

11. It may be accepted that the upper Rockaway, above Dover, coming from the same country, and fed moreover in part by Green Lake, 130 feet higher than Hopatcong itself, must be at least equally as pure as the latter.

12. The combined water-shed of Hopatcong and the Rockaway above Dover, measures 72 square miles; equivalent to an average daily supply of at least eighty million gallons, or say, in round numbers, 30,000,000,000 gallons per year, of water ranking among the purest in the world.

13. Were a large reservoir constructed among the hills of the highlands, somewhere about Boonton or Montville, to which this water could be brought through the canal, from fifteen to sixteen miles of piping would carry it to Belleville, with a head sufficient to raise it to the highest parts of Newark, or of Bergen Hill and the Palisades.

14. At the same time the Pompton feeder could deliver, at Bloomfield, through the long level, for all business, steam and manufacturing purposes, such copious supplies of water, equal in purity to any river of equal volume in the United States—for example, of fully twice the purity of the Croton—that your cities would at once become, in this truest and most beneficent of all wealth of cities, quite as rich as Imperial Rome of old, in her halcyon days.*

15. In conclusion, taking in view all the results of my labors dur-

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* Rome, under the Emperors, when she was mistress of the civilized world, had a daily supply of pure water for every man, woman and child of more than three hundred gallons.

ing the year past, in the field and in the laboratory, I cannot hesitate to enounce, as my professional opinion, that if it is true that the opportunity now offers (as is stated to me) for your honorable Commission to convert the Morris canal from what is said to be an unprofitable channel of navigation, into a channel of pure water-supply for the great cities now growing up around us, this opportunity should be availed of immediately, without any dangerous delay.

All of which is respectfully submitted.

HENRY WURTZ.

On Chinese and Japanese Bronzes.—In the Paris Exposition of 1869, many bronzes from China and Japan were exhibited, which were of remarkable beauty, and which attracted great attention on account of the dead black color of their patina. The composition of these bronzes was, at that time, unknown. Lately, however, M. Henry Morin, of the Paris Conservatoire, has made an investigation of these bronzes, the results of which he has communicated to the Academy. They are interesting as well from a metallurgical as from a scientific point of view. What chiefly distinguishes these Chinese and Japanese bronzes is the large quantity of lead which they contain, in comparison with that used in European bronzes. On an average these bronzes were found to be composed of copper, eighty parts; lead, ten parts; tin, four parts; zinc, two parts; the remaining four parts consisting of iron, nickel, arsenic, sulphur and gold. In certain of the specimens analyzed, the lead much exceeded the amount above given, rising sometimes to even twenty per cent; but in these specimens, the content of tin was also increased, rising even to seven per cent. Such an alloy, however, has but little strength. The bronzes containing ten per cent. of lead possess rather remarkable qualities. They can be cast with facility, they are close-grained, and they take very quickly, when heated in a muffle, the black patina above mentioned. This patina, which had been supposed to be due to a special varnish, belongs really to the metal itself, being produced as above. To obtain successful castings with these bronzes, it is necessary that the objects produced should be quite thin.

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EDITORIAL.

ITEMS AND NOVELTIES.

The Franklin Institute Exhibition for 1874.—In the June number of this Journal, we gave in full, the Rules and Regulations governing the deposit of articles at the Exhibition, and the competition for premiums. In this number will be found the rules for the competitive trials of Steam Engines and Boilers.

The general rules in relation to the awarding of Premiums, differ essentially from those of similar Exhibitions elsewhere. As already stated in the address of the Board of Managers, "in the earlier Exhibitions of the Franklin Institute, a list of Premiums was published beforehand, but experience proved that many of the medals were neither earned nor awarded, while the acknowledged excellence or novelty of other articles exhibited, compelled the award of medals which had not been proposed." This plan was abandoned in 1838, and the following adopted in its place, as given in Rule 11, viz:—"All articles entered for competition will be carefully examined by the Judges, and Premiums will be awarded on such articles as they shall declare worthy—their decisions being based on intrinsic merit, and not because the article happens to be the best exhibited in any particular class."

The adoption of this plan has had the effect of raising the standard of excellence of the exhibits, and also of greatly enhancing the value of the Premiums awarded by the Institute.

The rules for testing Steam Engines and Boilers are the result of careful consideration by a committee, each member of which has given the subject much study; and it is believed that they embrace all that is necessary to secure accurate results. Every facility will be given for comparing the efficiency of the various Boilers exhibited, by weighing the water and fuel, and also by working the steam through an Engine when practicable, and measuring the power developed both by indicator and dynamometer. Builders should not fail to embrace this opportunity of having their Boilers and Engines carefully and thoroughly tested. The preparation for a supply of water to all classes of Pumps is most ample, and of simple character, and cannot but be satisfactory to exhibitors, saving them much labor and greatly reducing the cost of putting Pumps in operation.

Applications for space are coming in freely, especially for machinery in motion, which will occupy fully one-third of the building. Persons proposing to exhibit, should therefore send in their applications soon, to secure eligible locations.

The Committee has been put in possession of the building two weeks earlier than was promised by the Railroad Company, and the work of preparation is being pushed forward rapidly, so that exhibitors need have no fear about its being ready by the 14th of September, the time announced for receiving goods.

Persons desiring further information will receive prompt attention either by addressing the Committee on Exhibitions, Franklin Institute, or by calling in person on the General Superintendent at his office, south west corner of Thirteenth and Market Streets. K.

A Typical Sun-Spot.—We take great pleasure in calling the attention of our readers to the exquisite steel-plate which illustrates Professor Langley's interesting paper on the Solar surface, printed in the present number of this Journal. We do this for two reasons: In the first place because of the skill and fidelity with which Professor Langley has drawn the spot, as observed in his 13 inch refractor. It is well known that the minute details of the photosphere and of the spots cannot be secured by photography owing to their rapid changes and the tremor of the atmosphere under the high power necessary for their observation. Professor Langley tells us that he has taken the general contour and many of the details from the great spot of

December 23 and 24, 1873; but that he has added to the picture the results of numerous studies of detail in other spots, made during the past two years. While, therefore, this is a typical-spot in the sense of being completed from several observations, it has nothing theoretical about it; everything, even the minutest details, having been actually observed. In the second place, we ask attention to this plate because of the marvellous quality of its execution as an engraving. This we owe to a new process devised by Mr. Samuel Sartain of this city, so well known throughout the country for the high character of his steel-engravings. By this improvement the enormous labor of transferring the minute details of such a picture as this to the steel plate has been obviated and the cost of engraving drawings of this character upon steel, proportionately reduced. We believe we hazard nothing in saying that this plate is by far the finest yet produced of the solar surface. The double-spot drawing, which was reproduced as an Albertype for the *American Journal of Science* for February, has excited the liveliest interest in Europe and has been the occasion of repeated discussions in the French Academy; but the present drawing, executed thus exquisitely upon steel by Mr. Sartain, cannot fail to awaken still greater interest and to be treasured as the latest and best work of the kind done in solar physics.

The Chilian International Exposition of 1875.—By a decree of the Government of the Republic of Chili, an international Exposition will be opened at Santiago on the 10th of September, 1875. This Exposition has for its object not only to make known the progress which the Republic has made since the last exhibition in 1869, but also to stimulate the development of new industries and improved processes, and thus to increase the national production. Chili fully recognizes the great value of her natural productions, especially her mineral salts; and therefore seeks, in this way, to introduce into the country the knowledge necessary to develop these possessions and the inventions by which they may be most economically utilized. The articles designed for the Exposition are classified in four sections, each containing several groups. These are: I, Natural products in the crude state; II, Machinery; III, Manufactured articles; IV, Fine arts. Beside these, there is a special section devoted to public instruction. Applications for space should be addressed to the President of the International Exposition of Chili of

1875, at Santiago, in season to reach that city before the first of January, 1875. Articles included in sections I, II, and III, will be received only between the 1st of March and the 15th of August. Articles belonging in section IV, and in the special section of public instruction, will be received up to the 25th of August. All objects forwarded for exhibition should have a card attached, upon which is indicated: (1) The name of the exhibitor; (2) His residence and address, the price of the article, whether it is to be sold, and any other necessary explanations. Exhibitors having machinery in motion, should indicate in their application the character and object of their machines, and the motive power required. All exhibitors to this Exposition will be entitled: (1) To a reduction of fifty per cent. of the cost of railway transportation between Valparaiso and Santiago, and over all other State railways; (2) To free entry of all articles included in sections I, II, and IV, and the special section of public instruction; articles coming under section III, will pay the respective duties when withdrawn from the Exposition for sale; (3) The commission agree to contribute the sum of 200 francs toward defraying the traveling expenses of any special workman charged with the care of any of the machines or industries sent to the exhibition: these workmen having a *visé* upon their passports by the Chilian consul at the port of embarkation, stating that they visit Chili for the above purpose. Concessions from the steamship lines running to Valparaiso, on freight and passage, are expected.

Non-Combustible Wood.—The English Admiralty have recently made some quite satisfactory experiments at Plymouth, upon a wood rendered uninflammable by treatment, which it is proposed to use in the construction of naval vessels. These experiments were superintended by Vice Admiral Sir William Hall, the wood being rendered non-combustible by treatment with a solution of sodium tungstate. The results prove that wood thus prepared is very much less inflammable than ordinary wood; chips and shavings made of it, though of course capable of being destroyed by fire, cannot be themselves inflamed, and cannot of course communicate fire to masses of wood thus prepared; so that frame work made of this wood resists flame perfectly, at least when not exposed for a long time to a fierce fire. These advantages, however, are diminished by the considerable first cost of preparation, as well as by the increased weight of the wood after treatment. Before giving to the inventor of the process, Dr. Jones, the sum asked by him for the use of his process in the British navy, the Admiralty have ordered new experiments. Two small vessels are to be immediately constructed, of exactly the same size and character, the one of the prepared wood, the other of ordinary wood. They are then to be similarly prepared and fired. In this way, it is believed that the real value of this method, if not in preventing, at least in retarding, fire on shipboard, may be satisfactorily tested.

The Gramme Machine as a Source of Power.—The new thermo-electric battery of Clamond seems fully to answer the expectations at first formed. For galvanoplastic work it has already been adopted in many of the large establishments of Paris. It is now proposed to combine it with the Gramme machine to form a motor for light work. Recent experiments have shown that the ordinary small Gramme machine, used for illustrating the principle only, can furnish when driven by three Bunsen cells, a force of two kilogram-meters. Now since two Clamond elements yield the same amount of electricity as three Bunsen elements, and consume 300 liters of gas per hour, it follows that the above amount of power, abundantly sufficient to run a sewing machine for example, can be furnished at an expense of 1500 liters of gas for five hours' work, at a cost here in Philadelphia—assuming gas to cost $2.25 a thousand feet—of nearly twelve cents.

On the High Temperatures Actually Possible.—Several memoirs upon the highest temperatures actually and theoretically attainable have lately been presented to the French Academy. M. Cailletet has been studying the influence of pressure on combustion. He finds, by means of an ingenious apparatus in which he has been able to burn not only a candle, but also a wick fed with alcohol, in highly condensed air, that the light gradually increases with the compression, finally becoming dazzling and so brilliant as to rival that of phosphorus in oxygen. But then, however, if the pressure be increased, the brilliance of the light diminishes, the flame becomes smoky and flakes of lamp-black are deposited. From this it is clear that the temperature of the combustion increases with the pressure up to the point of dissociation of the hydrocarbon gases of the candle. The same fact was shown by the spectrum; the spectrum increased with the temperature up to a certain limit, which could not readily be passed. From these facts Deville draws the conclusion that it is very decidedly an error to estimate the sun's temperature at several millions of degrees. These experiments, as well as those of Berthelot and his own, go to show that there is a limit to possible temperatures and that a burning body cannot produce heat of an indefinite intensity. "Perhaps" he says "the temperature of 2000°C. is the highest temperature which can exist in the universe." M. Violle concludes from some experiments which he has made, that there cannot be a temperature higher than 1400°C, anywhere.

The Suez Canal.—The last Bulletin of the Suez Canal Company contradicts the rumors which have been circulated, particularly in England, concerning the filling up of the canal with sand. It asserts that the experience of the past five years has shown that it may be kept open without special difficulty. With reference to the Austrian Corvette Friedrich, which, it had been asserted, was grounded two days and two nights in the canal, and was three days in getting through, the Bulletin gives the following facts: The corvette left Port Said, on the 31st of May, at 4.50 P. M., and arrived at the gates of kilometer 24 at 7.45; at 8.44, one hour after, she was through and the next morning, June the 1st, she left for Suez, where she arrived without difficulty. Moreover, this corvette drew only 5·9 meters of water; while vessels have passed through both before and since, drawing much more. Thus for example, on the 31st of May, the English steamer Ajax passed through, drawing 7·16 meters; June 26th the English steamer Eldorado, drawing 6·81 meters; June 13, the English steamer Coromandel, drawing 6·86 meters; and on June 28th, the English steamer Qwang Se, drawing 7·01 meters. The company is in possession of no facts which gives it any apprehension that the canal will not readily be kept navigable for vessels of the largest class.

Krupp's Heavy Guns.—We find in the *Revue Industrielle* the following particulars concerning the heavy guns already made and to be made at Krupp's mammoth establishment at Essen. The guns are all made of a special quality of crucible steel. They are all rifled and all have the cylindro-prismatic breech-plug characteristic of Krupp's system. The carriages for naval and coast-service are generally of iron, with axles, rollers, bolts and brakes of cast steel. The guns intended for ship's or for shore use are as follows:

1. A cannon of ·305 meter (twelve inches) diameter, mounted on a shore-carriage weighing 36600 kilograms (36 tons). The steel shell

when charged weighs 296 kilograms (650 pounds,) and the firing charge of prismatic powder is 60 kilograms (132 pounds). The weight of the carriage and chassis is 21 tons.

2. A howitzer of ·28 meter (11 inches) diameter, mounted on a shore-carriage, and weighing 10 tons. The weight of the carriage is 9220 kilograms (9 tons). The cast-iron shell weighs 199 kilograms, (440 pounds,) and the firing charge of powder is 20 kilograms (44 pounds).

3. A short navy gun ·26 meter (10·2 inches) diameter, mounted on battery-carriage, weighing 11800 kilograms (11·6 tons). The weight of the cast steel shell charged is 184 kilograms (405 pounds,) and the charge of prismatic powder for the gun is 37·5 kilograms (8·25 pounds). The carriage and the chassis weigh 8·5 tons.

4. A long cannon ·24 meter (9.4 inches) diameter on a battery-carriage, weighing 15500 kilograms (15·25 tons). The weight of the cast-steel shell charged is 135 kilograms (300 pounds,) the charge of prismatic powder is 24 kilograms (60 pounds) and the carriage and chassis weigh 7·5 tons.

5. A long gun of ·21 meter (8·2 inches) on a shore-carriage, weighing 10 tons. The cast-steel shell charged, weighs 95 kilograms (210 pounds) and the firing charge is 17 kilograms (37·5 pounds) of prismatic powder. The carriage and chassis weigh 7 tons.

6. A long cannon of ·17 meter (6·6 inches) diameter, weighing 5·5 tons. The weight of the cast-steel shell charged, is 55 kilograms (121 pounds,) and the firing-charge is 12 kilograms (26·4 pounds). The carriage and chassis weigh 3·4 tons.

7. A long gun ·15 meter (6 inches) diameter, on a navy carriage. Its caliber is ·1491 meter (5·8 inches,) its length, 3·850 meters (12·7 feet,) length of bore, 3·43 meters (11·3 feet,) weight of cannon 4 tons, preponderance at the beginning of curve of breech 75 kilograms (165 pounds). This gun has 48 riflings, all parallel; the width of the grooves being 3 millimeters (·118 inch,) and the pitch of the twist 9·7 meters (32 feet), weight of the cast-steel shell charged, 35 kilograms (77 pounds); charge of prismatic powder 8 kilograms (17·6 pounds); initial velocity, 460 meters (1518 feet). Weight of elongated cast iron shell charged, 28 kilograms (61·6 pounds); firing charge 6·5 kilograms (14·3 pounds); initial velocity 465 meters (1533·5 feet). The carriage of this gun is designed for corvettes, or for vessels of war of the same class. It is a chassis-carriage, furnished with a friction brake to check the recoil in addition to the ordinary

pulley. The elevation is taken on a toothed arc, and the lateral direction is fixed by ropes and pulleys attached to eye-bolts in the rear of the chassis, as is usual; the chassis rests on semi-circular rails, whence any lateral direction may be given to the gun. The height of the gun support is ·960 meters (3·17 feet); the weight of the carriage proper is 1505 kilograms (3311 pounds) and the weight of the chassis 935 kilograms (205 pounds; the weight of the whole being 2440 kilograms (5368 pounds).

8. Finally the last naval gun upon the list is a cannon ·12 meter (4·7 inches) mounted on a sea-carriage. The weight of this gun is 1400 kilograms (3080 pounds); the preponderance of the breech 100 kilograms (220 pounds), and the bore is rifled with 18 grooves. The cast steel shell charged weighs 17·5 kilograms (38·5 pounds) and the firing charge of ordinary coarse-grained powder is 3·5 kilograms (7·7 pounds); the initial velocity under these circumstances being 450 meters (1500 feet). The carriage is upon wheels intended for use as a battery or upon the spar deck of war vessels of small tonnage. It weighs 895 kilograms (1970 pounds).

Since the Vienna Exposition, the works at Essen have projected the manufacture of three new guns of large caliber, of which the following are the details:

No.	Diam.	Weight complete.	Prepon. of breech.	Length of rifling.	Diam. of rifling.	Cst iron shell charg'd	Steel shell charg'd	Firing charge.	Elong. shell charg'd	Firing charge.
	cm.	kilos.		mm.	mm.	kilos.	kilos.	kilos.	kilos.	kilos.
1	35½	57500	——	5260	363	480	474	95	409	82
2	40	82000	——	5900	409	685	675	135	580	111
3	46	124000	——	6430	470	1040	1025	200	800	175

The length of the rifling above given, corresponds respectively to 14·82, 14·75 and 13·97 calibers. It is estimated that the first of these guns will entirely penetrate, with both the steel and the chilled iron projectiles, a plate of iron 41·85 centimeters thick (16·5 inches) upon a backing similar to that of the Bellerophon, placed at a distance of 500 meters (550 yards) or a plate of 36·6 centimeters (14·5 inches) at a distance of 2300 meters (2530 yards). The last of the guns above described is expected to be capable, with the most effective projectiles of penetrating a plate 47 centimeters (18·5 inches) thick, backed as before and placed at a distance of 2900 meters (3200 yards). Since it has already been found entirely possible to carry two guns weighing 36 tons each—72 tons in all—upon a turreted vessel, it would seem that a similar vessel of war might be constructed to carry either in a turret or on a revolving platform, two of these largest cannons, weighing only 57 tons each. The projectiles from such a gun would destroy, even at the longest ranges, the heaviest armor at present existing upon any vessel of war. To resist these frightful missiles, plates of 61 centimeters (24 inches) in thickness would be necessary; such plates for example as the Inflexible, a ship actually in course of construction in England, will have for her armor. The above cannon of 35 centimeters diameter, with its carriage and the material necessary for 100 shots, would weigh 126·5 tons.

New Photographic Method for Observing the Transit of Venus.—The celebrated French astronomer Janssen, has recently brought before the Academy an ingenious apparatus which he had devised for ascertaining the precise instant of contact of the planet Venus with the limb of the sun on the approaching transit of the 10th of next December. The difficulty of fixing the exact time with the telescope is due, as is well known, to the formation of a black ligament uniting the two. In Janssen's apparatus, a movable disk, having toward its edge equidistant round openings, turns before a second disk covered with sensitive paper. By means of clock work, the outer disk is made to move every second over a distance equal to the diameter of one of its openings. Hence every second there is a new plate exposed, and a new picture taken. By examining each picture, it is possible to determine exactly the time of contact.

Projected Tunnel under the Simplon.—A short time ago a proposition was made in the French National Assembly to effect a loan of 48 millions of francs for the purpose of constructing a tunnel under the Simplon pass. The subject was referred to a commission, and this commission has recently reported through M. Cezanne. The great advantage offered by the Simplon route is that it shortens the distance between Paris and Plaisance (Italy) by 67 kilometers over the Mt. Cenis route. But in such a case the horizontal distance is by no means the only one to be considered; the altitude is also of great importance. In this respect, too, the Simplon route has great advantages, since it is 503 meters (1660 feet) lower than that by Mt. Cenis and 369 meters (1218 feet) lower than that of St. Gothard. Unfortunately, however, these advantages are in great part neutralized by the necessity which this route imposes, of traversing the Jura, which would require a grade of twenty to twenty-five feet in a thousand. Indeed, the route from Paris to Milan by the Simplon would find its highest altitude—at least 1100 meters—not in the Alps, but in the Jura. Moreover in discussing this question it is often assumed that a tunnel virtually suppresses the Alps, the railway passing directly from the French to the Italian plains. But this is far from being the case. It is indeed true that on the northern side, the foot of the Simplon may be reached through the Rhone valley by a grade not heavier than fifteen feet in a thousand —though only, as just stated, after traversing the Jura at an altitude of 1000 meters by a grade of twenty to twenty-five feet. But on the southern side, the Simplon tunnel issues at least 100 meters above the plains of Italy, to reach which a grade of twenty-five feet in a thousand is necessary for a distance of twenty kilometers. These disad) vantages seem to the Commission to more than counterbalance the advantage of shorter distance between Paris and Plaisance. But another question here arises. Will the Simplon tunnel divert toward France the traffic from Belgium and northern Germany, sure without it to go to the St. Gothard tunnel, not being available for that of Mt. Cenis? A glance at the map answers this question. The Simplon is very near St. Gothard; the two tunnels would not be more than fifty kilometers apart, at their northern ends. In issuing from the St. Gothard tunnel and following the course of the Rhine, the descent is easy and without a break to Basle, Cologne, Antwerp; while in leaving the Simplon tunnel, the railway, turned westward by the high chain of the Jungfrau, is obliged to traverse the Jura, is repelled by the Vosges, checked by the Ardennes and only reaches the low lands of Belgium, Holland, and Germany with difficulty. An examination of the route by these two lines, from Basle—at the head of the great Rhine plain and easily accessible to Switzerland, Alsace, and Germany —to Milan, the point in Italy where they both unite, will strengthen much the negative answer to this question. M. Stockalper, a Swiss engineer, himself interested in the Simplon scheme, has published some important data of cost, in this connection. He finds that to transport a ton of goods from Basle to Milan by the St. Gothard tunnel would cost 21·46 francs; while by the Simplon tunnel it cannot be done for less than 23·28 francs. These considerations are conclusive with the commission; and they close their report with the following words:

"When numerous enterprises, purely French in their character, are obliged to suffer postponement for want of resources, we cannot undertake a foreign work of the magnitude of the Simplon tunnel.

France is to-day in the situation of a large landed proprietor who has seen his territory invaded, his crops destroyed, his dwellings burned. It is in vain that his interest is solicited in laying out a road through an adjoining property, while his own ruins are yet unrebuilt, and his own grounds are still unrestored."

The Light of Coggia's Comet Polarized.—Professor Wright, of Yale College, publishes in the *American Journal of Science* the results of his observations with the polariscope upon the light of Coggia's comet. During the greater portion of the time when the comet was favorably situated for observation, it was unfortunately hidden by clouds or extinguished by thick haze. On one or two occasions, however, he was able to obtain evidence that its light was polarized. The instrument made use of was the very sensitive combination with which his observations upon the zodiacal light were made. On the evening of July the 6th, although the sky was generally full of drifting clouds clear intervals appeared now and then, which allowed a distinct view of the comet. The polariscope showed the bands, both bright and dark, quite definitely, and they were seen with comparative ease. Observations repeated a number of times agreed in showing that the light was polarized in a plane passing through the axis of the tail ; that is, as nearly as could be estimated, in a plane passing through it and the sun. Other observations made on the evening of July 14th, when the sky was quite clear, gave the same result, though less satisfactorily, as the twilight had begun to interfere with the observations. After waiting until this had disappeared, it was possible to see the bands, though with some difficulty, and the degree of the polarization appeared to be decidedly less than on the previous occasion. The percentage of light thus polarized could not be accurately fixed, but it was not large. The conclusion is therefore that a considerable portion of the light of the coma is derived from the sun by reflection.

Impermeable Paper.—By plunging a sheet of paper into an ammoniacal solution of copper for an instant, then passing it between the cylinders and drying it, it is rendered entirely impermeable to water, and may even be boiled in water without disintegrating. Two three, or any number of sheets thus rolled together become permanently adherent, and form a material having the strength of wood. By the interposition of cloth or of any kind of fiber between the layers, the strength is vastly increased.

Meteoric Occlusion of Hydrogen.—In a paper read at the recent meeting of the American Association at Hartford, upon the use of iron tubes, externally glazed, for nitrogen determinations, by Professor A. P. S. Stuart, the author showed that the hydrogen of the coal gas employed for the combustion, passed freely through an unglazed tube at a high temperature. Since the hydrogen previously occluded by iron meteorites, would be discharged again by the high temperature caused by ignition in our atmosphere, were this ignition to take place throughout their mass, Professor Stuart suggested the hypothesis that the hydrogen which they contain was occluded on striking the moist earth; the incandescent mass first decomposing the water in the soil, and then occluding the evolved hydrogen. In the discussion which followed, Dr. Lawrence Smith inclined to the hypothesis, that the heating of a meteorite in our atmosphere was merely superficial, and that therefore, the occluded hydrogen in its interior was retained.

The St. Gothard Tunnel.—On the 30th of June last, according to the monthly report of the Federal Council, the St. Gothard tunnel had pierced the mountain to a depth of 1956·8 meters (6418·3 feet); nearly one-seventh of the entire distance, which is 14920 meters (48937·6 feet). During the month of June the advance was 133·4 meters, of which 70·3 meters was on the Gœschenen side, and 63·1 on the Airolo side. The enlargement of the tunnel was carried on through a distance of 1362·4 meters. The mean number of workmen employed has been 1744; the maximum number 2076. On the Gœschenen side, the tunnel traversed a granitic gneiss, intersecting at the 999th meter a quartz pocket two meters long. The rock was in general quite dry, although occasional talcose fissures occurred, in which there was moisture. At the heading, six Ferroux drills are in operation, the average daily progress being 2·342 meters. For trimming, the machines of Dubois, Francois, Sommeiller and McKean are in use; beside these, hand-drills are also used. On the Airolo side, the tunnel has traversed a quartzose garnet-bearing mica schist, intercalated with hornblende schist and massive hornblende. Many fissures were met, from which water issued, at a temperature of 10·7° to 11·3°C. The rock itself, however, was quite dry. The drills used were those of Dubois and Francois, and latterly the improved drill of McKean. The mean progress at this end has been 2·1 meters per day. The trimming and enlargement has been effected by eight Sommeiller machines.

Editorial Correspondence.

Gohlis, Leipzig, March 20, 1874.

To the Secretary of the Franklin Institute;

Dear Sir: I beg leave to inform you of a novelty in Mechanical Engineering, a description of which you will find in the annexed paper. As this invention has created quite a stir among our best engineers, I trust that you also will take some interest in it.

Yours Respectfully,

W. E. ABLAND.

A Petroleum Motor.

For a number of years, the tendency among Mechanical Engineers has been to substitute a cheaper and more convenient motor, for the always expensive Steam Engine, especially in those establishments that require a comparatively small working-power. This tendency has originated a new machine in addition to various engines of more recent notoriety (such as the Lenoir Gas Engine, the Lehmann's hot-air Machine, the Siemens' Motor and others) to which the name Petroleum Motor has been given.

Referring to the accompanying cut, Figure 1, we will explain the principle of this new machine, which has so largely attracted the attention of Engineering circles; inasmuch, however, as we are just about to secure a patent, we shall reserve for the present, minute explanation of the more important details. But we will

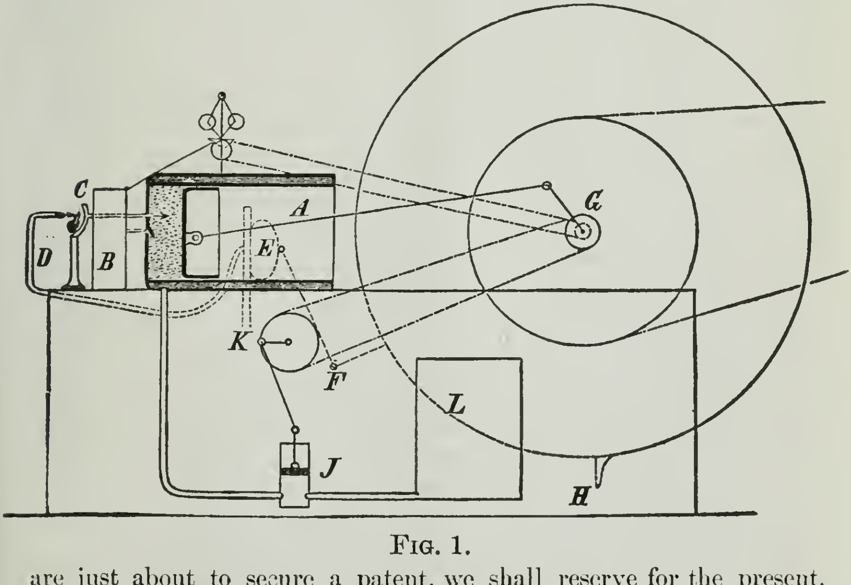

FIG. 1.

promise in a later description, to give such explanations accompanied with all the required cuts.

The principle of the Petroleum Motor is similar to that of the ordinary single acting horizontal steam engine, except that while the expansion of steam is employed in the latter, a quantity of petroleum converted into vapor is applied in the former to move the piston.

The double cylinder A, Fig. 1, contains at the bottom three valves, the middle one being provided with a nozzle covered with wire gauze. Through this the petroleum supplied from the vessel B, is forced or injected into the cylinder as a fine spray.

The second valve, above the one just mentioned, serves to allow a flame C, to come at the proper moment, in contact with the finely scattered petroleum which has entered through the said middle valve, and thus to cause its explosion. This flame C is driven through the second valve into the cylinder at short and sudden intervals, by a strong draft of air. When the explosion takes place, both valves, which open inwards, shut immediately, and the piston is driven forward. This piston is hollow, and to an inner partition the piston-rod is attached by means of a hinge and bolt, while the piston-rod itself is in direct connection with the crank G, to the axle of which, both the belt-pulley and fly-wheel are fastened. A projection H is fixed to the rim of the latter, in the form of an elongated cam or toe, pressing, at every revolution of the fly-wheel upon an air cushion E, thus effecting a flow of air through the pipe D. When the air reaches the flame in front of the valve, it causes a jet similar to that produced by a blowpipe; and this as indicated above, causes the ignition of the petroleum, and hence effects the explosion. The cushion is supplied with air by the pipe K.

The injection of the petroleum through the wire gauze is effected by means of a rarefaction of the air in the cylinder; this result is produced whenever the fly-wheel, by virtue of its vis viva, draws the piston back again partly through the cylinder.

The hollow space between the two cylinders is supplied with a constant flow of water, by means of the pump J, from the tank L, in order to keep the inner cylinder cool.

The governor on the top of the cylinder, whose motion is generated by bevel-gear and a band, has for its object to procure the proper quantity of petroleum by means of the compound lever shown in the figure. The smoke produced by the combustion of the petroleum passes, with the returning piston, through a pipe that communicates with a flue. The opening of the valve in question is effected at the proper time, by means of an eccentric fastened to the crank-shaft. In order to start the engine, it is only necessary to ignite the flame, and open the stop cock to let the petroleum rush in after one turn of the fly-wheel.

The firm, "Wiener Eisen und Maschinen-fabriks Actien Gesellschaft," in Vienna, where the Petroleum Motor is at present made, claims the following advantages over other similar Engines.

1. Perfect safety; neither incompetence or malice can cause a destructive explosion.
2. No particular attention needs to be given to the engine.
3. The facility with which the engine can be started and stopped; no complex preparations being necessary.
4. Its almost noiseless operation.

To these may be added economy of space, as no boiler or heating apparatus is required; and the cheapness of the Petroleum Motor itself.

The Petroleum Motor is built from 1 to 3 horse power, and the consumption of petroleum for a 1¼ horse power engine amounts to about 6 cents per hour.

Bibliographical Notices.

THE MANCHESTER STEAM USERS ASSOCIATION FOR THE PREVENTION OF STEAM BOILER EXPLOSIONS. *Chief Engineer's Report for January, February, March and April,* 1874,—*and Proceedings of the annual meeting of the Association, held March* 24*th,* 1874.

These Reports are both able and thorough, and contain much that commends itself to steam users in this country.

Beside an abstract from the record of inspections and an enumeration of the defects thereby discovered, there is a tabular statement of all the explosions which have occured in the district, giving the class or style of Boilers; the character of service; the nature of rents and other effects of the explosion; the verdict of the Inquest, and the number of persons killed and injured.

In some of the more important of these disasters, the Engineer of the Association was called as an expert witness before the Inquest, and has entered very largely into details, giving drawings of the Boilers, both before and after these explosions.

The thoroughness with which this work has been done, is only possible under such an organization as this, and it is just here that Americans should profit by their experience.

The policy of the Association is not to make dividends; but, believing in the absolute prevention of Boiler explosions, it uses the whole of the funds received from its members, exclusively for the good of these members, first by securing a careful inspection and supervision of their Boilers, and second by making careful scientific investigation into the causes of explosions, and the methods of their prevention, and by disseminating information in relation to economy of fuel, and proper management of Engines.

Nor are they niggardly in spreading the knowledge thus acquired, for they communicate it freely to the public press, and to the corresponding members in other parts of the world.

The value of this policy to the members, may be estimated from the fact, that during the nineteen years of the existence of the Association, no explosion of a boiler under its charge has occurred, while during only the four months covered by the report, there occurred in the same district, fourteen explosions of steam Boilers, killing thirty-six persons and injuring seventy-three others.

If then, this policy is productive of such excellent results, how much better it is than any simple insurance against the damage done to property by these explosions, leaving the much greater loss, that of life, entirely unprovided for, and leaving the insured in greater darkness as to causes and prevention, than before.

Whatever views may be entertained on all other points in reference to these subjects, we say, give us by all means, such thorough investigations as these; investigations by competent men who are in no wise dependent on, or influenced by the profit side of the accounts; and then spread broadcast the information thus obtained. K.

AN ELEMENTARY TREATISE ON STEAM. By JOHN PERRY, B. E., *Whitworth Scholar; Fellow of the Chemical Society; Lecturer in Physics at Clifton College.* 18 mo., pp. xii., 412. London, 1874. Macmillan & Co.

This little book of Mr. Perry's makes no pretension to exhaustiveness of treatment or to originality of fact. In his preface he acknowledges his indebtedness to the recognized authorities on the Steam-engine and offers the book simply as a text-book to those students who have but little Algebraical and Trigonometrical knowledge, and are acquainted with the simpler facts in Physics. The subject is treated in four books. Book I, considers the principles of Heat; Book II, Steam-engines and boilers: Book III, Locomotives; and Book IV, Marine-engines. These books are very minutely subdivided into chapters, of which the book contains forty-five; thus affording a pretty complete classification. To those chapters admitting of it, a valuable set of problems is appended, thus giving the student opportunity to test his knowledge at every step of his progress. We believe, however, he has attempted to treat too many subjects in too small a compass. Some of the chapters, as for example, the last one on Locomotives, which is on "Permanent Way," and which is a very extensive subject of itself, might with advantage, be omitted and its space be allotted to amplification in other directions; as for instance, in that of Compound engines. We doubt not this little book will be of essential service to students and we commend it to their notice.

Abstract from the Engineer's Journal of the U. S. Coast Survey Steamer "Hassler," with calculations, showing the performances of the Steam Machinery under conditions of substantially uniform operation, at sea.

Runs.				Steam Pressure.		Cut off per Indicator.	Throttle	Vacuum.	Wind and Sea. Sail.	Speed.	Average Revolutions per Minute.	Indicated Horse Power.	Coal per Hour.		Coal per Indicated Horse Power per Hour.	Variety of Coal.	Concentration of Water in Boiler.	Ashes per Hour.	Barometer.	TEMPERATURES					
																				AIR.			WATER.		
	Directions.	Date	Duration.	In Boiler.	In Cylinder.								By Account.	Actual, by Bunker Meas'ments.						On Deck.	Engine Room.	Fire Room.	Sea.	Disch.	[illegible]
		1872 Inclusive.		Lbs.	Lbs.	Prop.		Ins.		Knots.			Lbs.	Lbs.	Lbs.		32ds.	Lbs.	Ins.	Degs.	Degs.	Degs.	Degs.	Degs.	Degs.
A	Panama to Tartar Shoal	July 24 to 31	180 hours or 7½ days.	68·11	62·93	·32	Wide Open.	23·30	Most of the time light variable winds, permitting a little sail to be set. Sea smooth except for a short time on fifth and sixth days.	6·96	61·440	112·35	224·90	238·39	2·122	Cardiff.	1·37	61·73	29·88	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B	Acapulco to Magdalena Bay	Aug. 7 to 12	114 hours or 4¾ days.	76·51	71·20	·31		19·64	Light variable winds and smooth sea, with sail set occasionally for 3½ days. Last 24 hours headwind and sea. Vessel making slow progress.	6·41	64·012	126·42	224·10	237·44	1·878		1·41	40·00	30·07	84·2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C	Magdalena Bay to San Diego	Aug. 15 to 17	72 hours or 3 days.	77·76	75·66	·41		16·08	Headwinds and sea early part of run. Light winds latter part. Some sail set. Light wind and sea on starboard bow.	6·28	65·080	152·85	276·89	293·41	1·920		1·26	60·00	30·04	64·3	[illegible]	91·6	[illegible]	[illegible]	[illegible]
D	San Diego, at sea, and return	Aug. 25	20 hours	76·00	69·00	·35		22·75	Mainsail and jib set part of the time.	7·34	65·305	138·70	224·00	237·44	1·712		1·58	40·00	29·63	——	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
E	San Diego to San Francisco	Aug. 29 to 30	35·03 hours.	78·53	70·00	·47		19·16	Light head wind. No sail.	6·55	68·113	171·32	280·00	296·80	1·732		1·55	61·66	30·05	——	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Mean 1·87

Civil and Mechanical Engineering.

PERFORMANCE OF THE COMPOUND ENGINES OF THE U. S. COAST SURVEY STEAMER "HASSLER."

By Charles E. Emery, Consulting Engineer.

[To the Editor of the Journal of the Franklin Institute:—

Dear Sir: By permission of Capt. C. P. Patterson, Superintendent of the U. S. Coast Survey, I forward, for publication, the following extracts from a report made to him by myself, as Consulting Engineer U. S. C. S., on the subject above indicated. The facts mentioned are of special interest, as the engine of the Hassler is believed to be the first built in this country to secure special economy for marine purposes, and was designed independently of the English practice and in fact in anticipation somewhat of the revival here of interest in Compound Engines. It will be observed too that special pains were taken to ascertain accurately the facts in regard to the performance. The report is dated November 1st, 1873. C. E. E.]

I transmit herewith an abstract of the Engineer's Journal of the U. S. Coast Survey Steamer "Hassler," with tabulated results founded thereon, showing the performance of the steam machinery, at sea, under conditions substantially uniform, but, on the whole, more unfavorable than in ordinary practice.

The abstract is made from the record of the run from Panama to San Francisco in July and August of last year (1872) that being the first time, after the engineers were furnished with complete blank journals and careful instructions suggested by former experiences, that the vessel was under steam for a sufficient period to furnish reliable information.

The steamer had just come from the Atlantic Coast, consequently some matters were out of repair: for instance a defective stuffing-box caused a poor vacuum, and a leaky tube in the condenser required the use of some salt water; both faults reducing the economy. So also the iron bottom of the vessel was very foul, which reduced the speed.

The steaming for the time included in the abstract, was made at half boiler power, which should have given, with clean bottom, an average speed of 7½ to 8 knots, under the conditions encountered.

Stops were made in various ports and for sounding and dredging purposes during the trip, so the abstract has been divided into five runs, designated by letters, during each of which the conditions were substantially uniform and the steaming continuous, except one stop for dredging in each of the two first; in these the whole watch of four hours, in which the stop was made, has been rejected, to secure the condition of uniform operation. The other columns will be understood from the headings. Following the abstract I give a brief discussion of portions of the same with references to other performances of the vessel. I also append for reference a short description of the vessel and machinery.

The following extracts from the instructions printed in the Engineer's Journal will show the precautions taken to obtain accurately the power developed and its cost in fuel:

"The steam pressures, vacuum, and positions of throttle and cut-off, as recorded, should be the means for the hours, and not simply correct records at the time of the observation. In case that by order or accident, the average conditions are abruptly changed during the hour, interlined entries should be made showing the average for each period, and the exact time of the change be noted in the remarks.

A complete set of indicator-diagrams should be taken at least once every day: for instance, shortly before meridian, at which time the position of the cut-off, throttle, and the steam pressure and other conditions should be regulated so as to represent, as nearly as possible, the average for the steaming done during the previous 24 hours. The diagrams necessary for a complete set should all be taken as nearly as possible at the same time, and the data provided for in the specimen diagram herein be collected and noted without delay. The diagrams and data should show the facts as they exist at the time; the object not being to obtain a maximum result or fair looking diagrams. The original diagram should be slightly secured with mucilage at its upper left hand corner, between the pages of corresponding date in the original journal. When experimenting, diagrams should be taken half hourly, in which case the name of the vessel and the date and time need only be noted thereon, and the other quantities can be obtained from the Journal.

The reading of the engine-counter should be taken exactly at the end of the hour by observing the second hand of the clock in connection with the other hands.

The *net* amount of coal used should always be entered in the log.

To check errors, the bunkers should be carefully measured when empty and drawn to scale, and after every fifteen days steaming, and just before coal is received, the coal in the bunkers should be trimmed to regular slopes, the amount measured and calculated, and the coal account corrected by an additional entry under the daily balance, as follows: 'Remaining as per measurement this day ——— pounds.' The plan of adding a percentage to each day's expenditure, or of charging for ship's use extraordinarily large amounts, is disapproved. The log should in all respects show facts as accurately as they can be ascertained; hence every deficiency or surplus should be recorded as soon as it is discovered, and the account adjusted at once."

During a previous voyage, the Commander of the vessel, to satisfy himself as to the accuracy of the coal account, had issued an order that the bunker doors be locked and opened only once in the watch in the presence of the engineer, when the coal for a watch was to be measured out. This system was productive of such good results that it was continued in connection with periodical measurements of the bunkers. Such measurement was made August 6th and again August 21st, and a deficiency in the coal account found amounting to 6·008 per cent., which could be easily accounted for by the few lumps that fell on the floor in measuring the buckets. This percentage was in later trials much reduced; but, not to overstate results, the amounts in column marked "Coal per hour by Journal" have been increased six per cent., and the augmented or actual amounts, recorded in the next column, have been used in the final determination of the cost of the power.

The above shows that, even with a comparatively small compound engine of good construction, each indicated horse power can be obtained, on regular duty at sea, for $1\frac{7}{8}$ pounds of coal per hour, or less than half that required with ordinary marine machinery of the old type, and hardly two-thirds that used, according to best testimony available, in the better class of large, direct-exhausting marine engines, using high pressure steam.

This cannot be called an experimental result. In fact the unfavorable conditions mentioned prevented it from being the maximum for regular sea duty. There is every reason to believe that, with careful attention, and both boilers in use, a result could have been obtained of $1\frac{1}{2}$ pounds of coal per horse power per hour. In fact some previous runs show this performance, but as they were made before the coal account was checked regularly by the bunker measurement, the results are not given in detail. There is, however, no reason to doubt their accuracy.

The vessel, on her trial trip, using Schuylkill coal and both boilers, developed 125 horse power with 250 pounds of coal per hour, a performance of two pounds of coal per horse power per hour, when the boiler and engines were not felted and the weather quite cold. The firemen, too, were not accustomed to the slow combustion obtained by using two boilers, and much watchfulness was required to ensure regulation by the dampers instead of by opening furnace doors. This difficulty caused a very great waste of fuel, afterward, when it was attempted to run moderately with both boilers on regular duty at sea, and finally it was actually found, in practice, that unless an engineer was kept constantly in the fire-room, it was far more economical to *force the fires* under one boiler at slow speeds than to use slow combustion in two boilers.*

Only one boiler was in use during the runs set forth in the foregoing abstract.

The following extracts, from the official report of Commander P. C. Johnson, U. S. N., commanding the Hassler, to yourself, may, I think, be considered in place in this report:

"It gives me pleasure to request your notice of the consumption of coal while engaged in such work as the Hassler was designed for. At San Diego, before starting the fires, the ship had in her bunkers 101·09 tons.

Today on hand	68·30	"
Deduct for distilling water, galley, stoves, etc., . .	3·60	"
Showing a consumption in 35 days of . . .	29·19	"
Averaging per day	0·83	"

The ship has been under steam every moment since leaving San Diego. Excepting Sundays she has been underway during the day, and banked fires at night, having steamed 1069 miles, and made 704, 026 revolutions. The bunker doors are closed and locked at all times, (except when in the act of getting out coal) and the key always in possession of the engineer. Besides weighing, the bunkers are frequently examined and their contents measured."

In a subsequent letter, Commander Johnson writes: "We have been 58 days under steam, running from daylight till dark, generally. Banked fires at night and Sundays, and have consumed in the furnaces only 1891·4 lbs of coal per 24 hours —0·844 tons per day.

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* An attempt is being made, however, to secure the economy due to increased heat-absorbing surface by using both boilers and reducing the grate surface with fire brick. So far it has been found that the steam can be carried more steadily, but no accurate determination can yet be given in regard to the question of economy.

There is no mistake about it. There has been no stealing of coal. The bunker doors were locked except when serving out, and the measurement shows the proper amount on hand now."

I submit that the above facts are sufficient to show conclusively the great economy which may be obtained by the use of the compound engine.

For convenience of reference, a general description of the Hassler is hereto annexed.

GENERAL DESCRIPTION OF THE U. S. COAST SURVEY STEAMER HASSLER.

The Hassler is an iron screw propeller of 350 tons burthen O. M. She was built at Philadelphia, in the year 1871, and is 151 feet long on load line, and has 24½ feet breadth of beam, and 10 feet depth of hold. Her rig is that of a three masted schooner, with lower masts of moderate length and tall top masts. The officers' quarters are on deck and are very commodious.

The vessel is propelled by a compound engine of 200 horse power. The cylinders are 18·1 and 28 inches in diameter, by 26 inches stroke, and are arranged one above the other, in the same line, with both pistons on the same rod, and operating the crank through a single connecting rod. The steam chests extend beyond the ends of the cylinders to reduce the length of the cylinder ports; but for simplicity of construction, the valve face of the upper cylinder is brought out in line with the other, and the valves of both cylinders are operated by the same rods. The upper cylinder is supported from the framing by four wrought-iron columns, and the two cylinders are sufficiently separated to allow the cover of the lower cylinder to be raised to obtain access to the piston. The bed plate is made of sufficient length to receive three bearings, in addition to which an independent thrust-bearing is connected to the same. The surface condenser is arranged under one side of the frames, and slants inward at the same angle as the latter. The circulation is performed by a centrifugal pump driven directly by a small engine. The air and feed pumps are vertical, and receive motion from the main crosshead through beams in the usual way. The necessary valves are provided, so that live steam can be excluded from the upper cylinder, and supplied direct to the larger one if desired. Ordinarily the steam passes to the upper cylinder, in which it is cut off at such point as to give the power desired, or usually at less than half stroke. The steam then passes to a large reservoir, placed under the main deck, through which it traverses slowly, thus permitting the water due to condensation for the work done, to become separated. From this reservoir the steam passes to the lower cylinder, but the supply is suppressed therein at such point as to keep the pressure in the reservoir substantially uniform. The lower cylinder communicates with the condenser in the usual way. The large cylinder and its bottom and head are steam jacketed. Drip vessels with glass gauges are provided to assist in blowing the condensed water from the jacket and reservoir. The propeller is a true screw, 8 feet 6 inches in diameter, with 13 feet pitch. At the hub the blades are rounded on both sides to reduce the resistance where the metal is thickest. The flat propelling surface gradually widens from the hub outward to 4 feet diameter, and the outer portions of the blades are of the ordinary construction.

Steam is supplied by two flue and return tubular boilers, each 6 feet in diameter and 12 feet long, and provided with a steam chimney. The total grate surface is 42 square feet, and the total heating surface 1400 square feet.

The shells are $\frac{3}{8}$ inch thick, with double riveted longitudinal seams. All flat surfaces are stayed 6 inches between centres. The boilers are considered of sufficient strength to carry regularly 80 pounds pressure for a series of years.

The maximum speed of the vessel, under steam alone, is $9\frac{1}{2}$ knots. Under steam and sail, she has made easily 10 and 11 knots. The ordinary speed at sea, under steam alone, is restricted by order to 8 knots, which can be obtained with one boiler under favorable circumstances.*

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* It will be of interest to add, in this connection, that the first reports as to the performance of the "Hassler" were unsatisfactory, owing to very bad management in the Engineer Department. The vessel left the Atlantic Coast in the fall of 1871, and as her commander found it necessary to take coal much sooner than was expected from results obtained on the trial trip, he instituted an investigation which had the effect, eventually, to make the performance all that could be desired, and to interest all on board in the matter, so that in fact a number of naval officers, then attached to the vessel, but who have recently returned to the East, have expressed a desire that the actual facts, as to the vessel's later performances, should be made public.

EXPERIMENTAL DETERMINATION OF THE CENTRE OF GRAVITY OF THE UNITED STATES STEAMER "SHAWMUT."*

By T. D. Wilson, Naval Constructor, U. S. N.

Naval Constructor's Office, Navy Yard, Washington,
May 8th, 1874.

To the Hon. Geo. M. Robeson, Secretary of the Navy:

Sir: In accordance with circular from the Navy Department, under date of March 17th, 1874, I have the honor to respectfully submit a report of an experiment made by me on the U. S. Steamer "Shawmut" the day before she sailed for Key West, for the purpose of ascertaining the height of her centre of gravity.

At the time this experiment was made the "Shawmut" was lying in the Potomac River, below the Navy Yard, Washington, D. C.

Although the wind blew a little fresh, there was no sea on, thus enabling the draught of water to be taken very correctly.

The ship was complete in every respect and ready for sea; the topsail yards were on the caps, sails all furled, boats hoisted, and the two broadside nine inch guns run out; the eleven inch pivot on the main deck, and the 20 pounder pivot gun on topgallant forecastle, were amidships and secured for sea.

She had on board a crew of about one hundred men, with provisions for the full complement for three months—32,295 pounds of water in casks and tanks, 208,320 pounds of coal in the bunkers, both boilers full of water, and steam up, the weight of water in the boilers being 53,000 pounds.

The estimated weight of the articles on board, coming under the Department of Equipment and Recruiting, excepting coal, was 108,160 pounds; the two lower anchors weighing 6,170 pounds, were down when the experiment was made. The total weight of ordnance, ordnance stores and equipments, was 117,113 pounds. Total weight of

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[* The following report to the U. S. Navy Department describing the experimental determination of the position of the centre of gravity of the U. S. S. Shawmut, has been kindly furnished us for publication. The officer who has signed this report is a well known naval constructor, and the author of a standard work on naval architecture used at the Naval Academy. The report is valuable as giving very clearly and concisely the method of performing an important but seldom practised manœuvre—one, however, which should always form a part of the preparation of a vessel for service. The loss of H. B M. ironclad "Captain," in consequence of the neglect of the Admiralty to determine the curve of stability of that vessel, was a warning which was not unheeded in Great Britain, and we may presume that it was understood by our own Navy Department. This report is transmitted to us by Professor Thurston, of the Stevens Institute of Technology, to whose collections its author had contributed a copy. Ed.]

engineers' stores and spare machinery 4,000 pounds. Total weight of carpenter's stores 7,068 pounds.

The conclusion that it would not be necessary to employ any other means to incline the ship, than that of shifting her guns, was arrived at with great satisfaction, on account of the great objection to having a large quantity of rusty pig iron upon the clean deck of a vessel in commission, the expense attendant on transporting it to and from the yard, and also because of the still further departure from the normal state of the ship which its presence would produce, and the necessity for still greater complexity in the calculations.

As this experiment was made for my own gratification, it was necessary that the consent of the commanding officer, Commander Henry L. Howison should be first obtained, which was freely given, and all the assistance he could afford was cheerfully accorded, for which, to him and his Executive Officer, Lieutenant Commander Norris, I am greatly indebted.

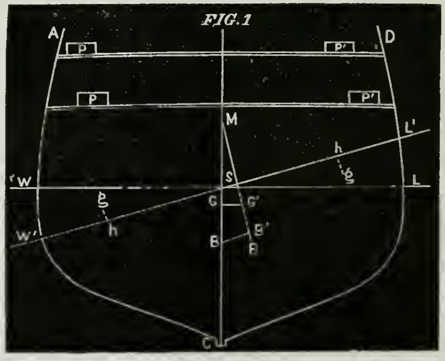
FIG. 1

As this is the only instance that I know of, where a U. S. Naval vessel has been experimented upon for this purpose (with the exception of the U. S. Steamer "Princeton," and Brig "Somers," which were inclined by Naval Constructor John Lenthall, late Chief Naval Constructor U. S. N., at the Navy Yard, Philadelphia, in 1844, an account of was recorded in the *Franklin Institute Journal;* the "Princeton" was inclined by moving weights on her decks, the "Somers" by hanging weights on her lower yard arms) I consider it necessary, in order that the subsequent portion of my report may be better understood, that I give a *rationale* of the experiment, which may be found recorded in the *Transactions of the Institution of Naval Architects* for 1860, as made by F. K. Barnes, Esq., member of the Council of Construction, H. B. M. N. Let A C D figure 1, represent the transverse section of a ship, through G the common centre of gravity of the hull, and every article on board; W L the load water line when the ship is floating in upright position; CBGM the middle line which is, therefore, perpendicular to WL, and also contains G, the centre of gravity of the ship, and B the centre of buoyancy (or centre of gravity of the displacement). Let also P represent a weight or weights on any or all of the decks, such as guns, shot, ballast, etc., capable of being readily transported to the opposite side of the deck or decks.

If the weight or weights P be moved across the deck to P′ the ship will incline through an angle W S W′, the amplitude of which will depend, *cæteris paribus*, upon the weight or weights moved, and the distance through which they have been moved.

When the ship has taken up the new position of equilibrium, the centre of buoyancy will have moved from B to B′, and the centre of gravity of the ship from G to G′, so that the line joining B′ and G′ will be vertical, and, therefore, perpendicular to W′ L′, the new water line, and will make the same angle B M B′ with the middle line B G M, as the water lines do with each other, and B′ G′ produced will meet in the middle line in a point M.

This point, in ships of the usual form, may, without any appreciable error, be assumed to coincide with the *metacentre* when the inclination does not exceed 4° or 5°.

From a general and well known property of the centre of gravity of a system of bodies, such as a ship, we know that since the weight or weights P have been moved in a horizontal direction to P′, the centre of gravity has also moved in the same direction; therefore G G′, the line joining the original and new centre of gravity, will be horizontal; and from another property of the centre of gravity we have that the weight of the ship×G G′=P× distance through which it has been moved; or if W represent the total weight of the ship, and c the distance through which the centre of gravity of the weight or weights P has been moved,

$$W \times G\,G' = Pc.$$

and

$$G\,G' = \frac{Pc}{W}$$

Now by trigonometry G G′=G M×tangent of the angle between the middle and the new vertical line B′ G′ M, i.e., the angle of the ship's inclination from the upright; or representing the angle of inclination by φ

$$G\,G' = G\,M \tan\varphi$$

$$G\,M = \frac{G\,G'}{\tan\varphi}$$

Equating the two values of G G′ thus obtained

$$\frac{Pc}{W} = G\,M \tan\varphi$$

or

$$G\,M = \frac{Pc}{W \tan\varphi}$$

The right hand member of this equation contains all known quantities after the ship has been inclined, and since the *metacentre* corresponding to any draught of water is easily obtained by calculation from the drawings of the ship, and its position fixed, the distance GM set off below it will give the position of the centre of gravity of the ship.

Finally the angle of inclination (φ) is found with the greatest exactness in the following manner:—

A T-square above twenty feet in length, with a wide, thick blade is nailed to the combings in the hatchways in a vertical direction, one in the main and one in the fore hatch. The two squares being independent of each other are intended to serve as mutual checks, and also to point out any racking of the ship, which might be occasioned by the movements of the weights on board.

From the upper edge of the head of the square, a distance of 20 feet is carefully set off upwards, and at the height thus obtained, a nail is driven into the board, and to it is attached a plumb line, the plummet hanging freely at some distance below the head of the square.

When the vessel is upright, and the experiment about to be commenced, the point where the plumb line intersects the upper edge of the head of the square is carefully marked; and when the ship has obtained her new position of equilibrium by the movements of the weights, the new point of intersection of the plumb line and the upper edge of the head of the square is marked in like manner. The distance in feet between the two points marked on the square, divided by twenty, will clearly give the tangent of the angle of the ship's inclination. The first thing done in commencing the experiment was to go to quarters; the powder division having been called on deck, the crew were divided equally on either side of the deck in single file, and along the edge of a seam in the deck, equidistant from the centre; the marines being divided and placed in a similar manner on the poop deck.

The two T squares having been fixed in position, and the draught of water noted, the men were cautioned to note their position so that they could resume it again when ordered to do so.

When all were again quiet, and the ship steady, the points in which the plumb lines crossed the upper edges of the squares were carefully marked as already described; an operation which occupied scarcely half a minute, and it is only during these short intervals, when the marks are being made, that the men need be under any constraint.

The men were then ordered to transport the nine inch gun from the port to the starboard side of the deck, placing it fore and aft the deck, as far out as it could be got, and close to the nine inch gun on that side. The nine inch pivot gun was then swung around to starboard and run out. The 20 pounder rifle on the topgallant forecastle was also swung around to starboard and run out; after all the guns had been moved the men were ordered to resume their stations as before directed. As soon as all were again quiet, the points in which the plumb lines crossed the upper edge of the T squares were marked at the same time; and the deflection of the plumb line, read off from both squares, was found to be sixteen inches.

The work of the crew here terminated, and by the movement of the guns above mentioned, a registered inclination was obtained, and data furnished, by which the centre of gravity might be found.

The weight of each gun moved was taken, and the distance through which it had been moved in a transverse direction, was then very carefully measured and recorded.

Thus ended the work on board the ship; the recorded draught of water at the lines of the above experiment was, forward 11 feet 0 inches, aft 13 feet 6 inches.

Displacement to the above line in tons 1010·84. Centre of buoyancy below water line 4 feet 6 inches. Centre of buoyancy above the lower edge of the keel 7 feet 6 inches. Metacentre above centre of buoyancy 7 feet $5\frac{1}{2}$ inches. Metacentre above lower edge of the keel 14 feet $11\frac{1}{2}$ inches.

The sum of the products of each weight, and the distance through which it was moved, was (in tons and feet) 199·32, and the deflection from the upright of the plumb lines in 20 feet was 16 inches; denoting by φ the corresponding angle, $\tan\varphi = \frac{1\frac{1}{3}}{20} = \frac{1}{15}$, $\varphi = 3^\circ\ 49'\ 21''$.

Weight of nine inch gun and carriage 10,437 pounds, moved 20·66 feet. Weight of eleven inch gun and carriage 24,159 pounds, moved 7 feet. Weight of 20 pounder rifle and carriage 3,793 pounds, moved 3·665 feet.

$G\,M = \frac{Pc}{W \tan \varphi} = \frac{199{\cdot}32 \times 15}{1010{\cdot}84} = 2{\cdot}958$ feet, centre of gravity below metacentre. The height of the centre of gravity above the lower edge of the keel 14·95 feet—2·96 feet = 11·99 feet. The height of the centre of gravity below the mean load line is, therefore, $\cdot 26 = 3\frac{1}{4}''$. Relative stability or displacement, multiplied by the distance between the metacentre and centre of gravity $1010{\cdot}84 \times 2{\cdot}96 = 2992{\cdot}0864$

The first instance in which this experiment was tried, to determine the position of the centre of gravity of a ship, experimentally, was on board H. B. M. Sloop "Scylla" and the "Rover," of eighteen guns, in Portsmouth harbor in May 1830. The experiment was made by a Mr. Morgan, of the School of Naval Architects, at that time the foreman of the Portsmouth dock yard.

No other experiments are recorded from that time up to 1855 (excepting those made on the "Princeton" and "Somers," before mentioned, in 1838, and found recorded in the *Franklin Institute Journal*) when by the upsetting of the Steam Transport "Perseverance" in the dock at Woolwich dock yard, the subject was brought under the serious consideration of Naval Architects. The determination of the metacentre and centre of gravity, is now made for every ship added to the English Navy.

The labors of Mr. Froude, and of other gentlemen who have devoted their attention to the subject of rolling of ships, has resulted in the establishment of two great facts. The first of these is that the principal thing (although not the only one) which influences rolling, is the distance between the centre of gravity of a ship, and the *metacentre;* the second is, that a ship rolling at sea is largely influenced by the period, etc., of the waves she meets with. Experience confirms the accuracy of both of these deductions.

Ships which have a great distance between the centre of gravity and metacentre are technically termed "stiff," and will spread a great amount of canvas, but they usually roll with violence.

On the other hand, ships which have a moderate distance between these points are not so "stiff," and roll moderately; while if the distance is very short, she will be "crank," and might, possibly, under some circumstances, be upset.

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Very Respectfully

Your Obedient Servant,

(Signed) T. D. Wilson, Naval Constructor, U. S. Navy.

THE THEORY OF AERO-STEAM ENGINES.

By J. A. Henderson, M. E.

[Continued from vol. lxviii., page 25.]

Before making any numerical calculations, the following general formulæ applicable to such an engine and boiler are introduced as embracing the main points of importance or of interest, and as serving for a common basis from which the several examples may be worked out by direct substitution.

The principal authority referred to for the constants used in calculation was Professor Rankine; and his nomenclature and fundamental equations were applied when practicable. The majority of the formulæ, however, and more especially those relating to the determination of the proportions of steam and air, by weight, and by volume before mixture, their tensions when mixed, and to the determination of the value of the constant γ for the mixture, were here deduced by the writer to meet the wants of the occasion, as no such formulæ could be found in published works.

All of the formulæ, other than those whose results are ratios, apply to such quantities as are produced by the entrance of one pound of air through the compressing pump, this mode of treatment greatly simplifying the relations between them.

The general method adopted for obtaining the effective work developed per pound of air admitted, by computing the work of expansion and compression from the theoretic forms of the diagrams, and taking the difference, was found to be the most satisfactory and direct under the circumstances.

It should be observed that the word *air*, owing to its shortness, is commonly employed to denote the *products of combustion*, except, of course, in those statements where the use of the more specific term becomes necessary.

Below is given the general notation to be used in the formulæ:

Pressures,

measured absolutely in pounds per square foot.

p_a = pressure of atmosphere.

p_1 = " in boiler and during admission in main cylinder.

p_2 = pressure of exhaust, = p_a when back pressure above atmosphere is not considered.

P_a, P_1, etc., the same measured in pounds per square inch, and above the atmosphere, except when otherwise stated.

Temperatures,

in degrees Fahrenheit.

t_a = temperature of atmosphere.
t_b = “ after compression in pump.
t_c = “ upon leaving the fire.
t_1 = “ of mixed air and steam.
t_2 = “ of exhaust.
t_f = “ at which feed water is supplied.

τ, τ_b etc., the same as measured from the absolute zero — 461.2° Fahr.

Weights,

in pounds per pound of air admitted.

w_c = weight of products of combustion.
w_s = “ “ steam formed.
w_1 = “ “ mixture of the two.

Volumes,

in cubic feet per pound of air admitted.

v_a = volume of one pound air when first admitted to compressing pump.
v_b = “ “ the same when compressed.
v_c = “ “ products of combustion at temperature of mixture.
v_s = “ “ steam at the same temperature.
v_1 = “ “ air and steam after mixture.
v_2 = “ “ mixture when expanded to atmospheric pressure.

Ratios.

r = ratio of expansion in main cylinder.
r_c = “ “ compression in pump.
r_p = “ “ boiler to atmospheric pressure.
g_w = “ “ weight of steam to products of combustion.
g_v = “ “ volume “ “ “ “ “ “
g_h = “ “ heat absorbed by steam to that remaining in air *above heat of compression.*

Those symbols relating to quantities of heat and work, efficiency, etc., are best given as they present themselves for discussion. The same is the case with the physical constants entering the calculations.

The quantities usually assumed as

DATA,

are P_a, P_1 and P_2, t_a, t_1 and t_f, from which p_a, p_1, p_2 and r_p, τ_a and τ_1 may be directly found; also H the total heat of combustion in foot-pounds, per pound of fuel, and N the number of pounds of air supplied for the same.

The points to be determined, are taken up in the order in which they naturally present themselves, beginning with the

HEAT OF COMPRESSION AND RATIO OF COMPRESSION IN PUMP.

Since the air is compresssd without gain or loss of heat,

$$\frac{\tau_b}{\tau_a} = \left(\frac{p_1}{p_a}\right)^{\frac{\gamma-1}{\gamma}} = r_p^{\frac{\gamma-1}{\gamma,}}$$

and

$$\frac{v_a}{v_b} = \left(\frac{p_1}{p_a}\right)^{\frac{1}{\gamma}} = r_p^{\frac{1}{\gamma,}}$$

where $\gamma = 1.408$ for air. From these two equations it follows that

$$\tau_b = \tau_a \, r_p^{\frac{\gamma-1}{\gamma}} \qquad \text{and} \qquad r_c = r_p^{\frac{1}{\gamma,}}$$

in which substituting the value of γ, and adapting to the use of logarithms, we get

$$\log.\ \tau_b = \log.\ \tau_a + 0{\cdot}29 \log.\ r_p \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\log.\ r_c = 0{\cdot}71 \log.\ r_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

from which t_b and r_o may be computed.

INITIAL TEMPERATURE T_c OF GASES LEAVING FIRE.

In finding this, t_h the temperature directly added by combustion, is first obtained by the formula

$$t_h = \frac{H}{772\,(1+N) \times 0{\cdot}238} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

the numbers 772 and 0·238, being Joule's equivalent and the specific heat of the products of combustion under constant pressure.

This temperature being added to that of the air leaving the pump, gives

$$t_c = t_b + t_h \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

RATIO OF HEAT OF COMBUSTION ABSORBED IN GASIFYING STEAM, TO THAT REMAINING IN AIR, ABOVE HEAT OF COMPRESSION.

On account of the transfer of heat in the boiler taking place at constant pressure, the quantities of heat are proportional to the changes in temperature, as is seen in the equation giving the desired ratio,

$$g_h = \frac{0{\cdot}238\ w_c\ (t_c - t_1)}{0{\cdot}238\ w_c\ (t_1 - t_b)} = \frac{t_c - t_1}{t_1 - t_b} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The percentages of heat entering steam and air, might, if necessary, be obtained from the formulæ

$$h_s = \frac{100 g_h}{1 + g_h} \text{ and } h_c = 100 - h_s.$$

WEIGHT OF PRODUCTS OF COMBUSTION PER POUND OF AIR ADMITTED.

$$w_c = \frac{1+N}{N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

PROPORTIONS BY WEIGHT OF STEAM AND AIR.

Since the steam is to be in such quantity, that the heat required to form it in the gaseous state at t_1° from the feed water, shall leave the air at the same temperature, and since the heat lost by the air is wholly taken up by the steam, we must have

$$0{\cdot}238\ w_c\ (t_c - t_1) = w_s \times h,$$

where h is equal to the total heat of gasification per pound of steam for any constant pressure, and has the empirically determined value of

$$1092 + 0{\cdot}475\ (t_1 - 32) - (t_f - 32)$$

thermal units. By substituting this in the previous equation and reducing, is obtained the following:

$$g_w = \frac{w_s}{w_c} = \frac{0{\cdot}238\ (t_c - t_1)}{1124 + 0{\cdot}475\ (t_1 - 32) - t_f} \quad \ldots\ldots\ldots\ldots (7)$$

$$\therefore \qquad w_s = w_c \times g_w \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

and

$$w_1 = w_c + w_s = w_c\ (1 + g_w) \quad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

PROPORTION BY VOLUME OF STEAM AND AIR.

For one pound of any gas we must have

$$\frac{p\ v}{\tau} = \frac{p_o\ v_o}{\tau_o} \text{ or } v = \frac{p_o\ v_o}{\tau_o} \times \frac{\tau}{p},$$

in which $\frac{p_o\ v_o}{\tau_o}$ is constant, and has for its value the difference between the dynamical specific heats under constant pressure and under constant volume, of the gas considered.

For air, $\frac{p_o\ v_o}{\tau_o}$ is equal to 53·15, and for steam 85·00 foot-pounds.

Since *the volume of the products of combustion is known to be almost exactly the same as that of the air supplied, for the same pressure and temperature,* in the present case v_c will be the volume of one pound of air at the pressure and temperature of superheating, or

$$v_a = 53{\cdot}15 \, \frac{\tau_1}{p_1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

The volume of the steam will be that of a weight w_s, at the same pressure and temperature, or

$$v_s = 85 \, \frac{\tau_1}{p_1} \times w_s \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

From v_a and v_e are directly obtained

$$q_v = \frac{v_s}{v_c} \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

and

$$v_1 = v_c + v_s \ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

Here, v_s, v_c and q_v, of course apply only to the volumes before mixture, as after mixture v_s and v_c each equal v_1 and $q_v = 1$. This diffusion of the air and steam to the same volume v_1, is accompanied by a corresponding fall in tension of each, but the sum of the two tensions remains equal to the pressure p_1 before mixture, and neither the resultant pressure, volume, or temperature is affected.

DETERMINATION OF THE VALUE OF γ, PROPER FOR MIXED AIR AND STEAM.

The general equation of adiabatic curves for any gas is

$$p = \text{constant} \times v^{-\gamma}$$

where γ is constant, and has for its value the ratio of the specific heat at constant pressure, to that at constant volume, of the gas under consideration.

Denoting by C^p_a and C^v_a, C^p_s and C^v_s, the specific heats at constant pressure and constant volume, of air and steam respectively, we thus have

for air
$$\gamma_a = \frac{C^p_a}{C^v_a} = \frac{0{\cdot}238}{0{\cdot}169} = 1{\cdot}408,$$

and for steam
$$\gamma_s = \frac{C_s}{C^v_s} = \frac{0{\cdot}480}{0{\cdot}370} = 1{\cdot}3$$

very nearly.

It should be mentioned that the specific heats of the products of combustion of all ordinary fuels, are stated by Rankine not to differ sensibly from those of pure air, and accordingly no distinction is here made.

To find γ_m, the value proper for air and steam mixed in the proportions already found, we may determine the two specific heats C^p_m and C^v_m of the mixture, and take their ratio.

As the weights w_s and w_c, bear to each other the ratio q_w, and have w_1 for their sum,

$$C^p_m = \frac{(C^p_a + q_w\, C^p_s)\, w_c}{w_1} \qquad \text{and} \qquad C^v_m = \frac{(C^v_a + q_w\, C^v_s)\, w_c}{w_1}$$

$$\therefore\ \gamma_m = \frac{C^p_m}{C^v_m} = \frac{(C^p_a + q_w\, C^p_s)\, w_c}{w_1} \times \frac{w_1}{(C^v_a + q_w\, C^v_s)\, w_c} = \frac{C^p_a + q_w\, C^p_s}{C^v_a + q_w\, C^v_s},$$

in which substituting the values of the several specific heats,

$$\gamma_m = \frac{0{\cdot}238 + 0{\cdot}48\, q_w}{0{\cdot}169 + 0{\cdot}37\, q_w} \dots\dots\dots\dots\dots\dots (14)$$

To use γ_m as thus calculated, it is necessary that the mixture be sufficiently superheated above the point of saturation of the steam, to keep the latter in the truly gaseous state, a condition that would probably be realized in most actual examples.

RATIO OF EXPANSION IN MAIN CYLINDER AND TEMPERATURE OF EXHAUST.

It is here assumed, owing to the insulating action of the air in mixture, and to the cylinders being properly clothed to prevent conduction and radiation, that no appreciable quantity of heat is lost, and consequently that the curve of expansion will be truly adiabatic, in which case, analogous to that of the compressing pump,

$$\tau_2 = \tau_1 \left(\frac{p_2}{p_1}\right)^{\frac{\gamma_m - 1}{\gamma_m}} \qquad \text{and} \qquad r = \left(\frac{p_1}{p_2}\right)^{\frac{1}{\gamma_m}}$$

or taking the atmospheric pressure for p_2, since $\frac{p_2}{p_1}$ reduces to $\frac{p_a}{p_1} = r_p^{-1}$

$$\tau_2 = \tau_1\, r_p^{\frac{\gamma_m - 1}{\gamma_m}} \qquad \text{and} \qquad r = r^{\frac{1}{\gamma_m}}$$

from which follow,

$$\log.\ \tau_2 = \log.\ \tau_1 + \frac{\gamma_m - 1}{\gamma_m} [\text{a. c. } \log.\ r_p] \dots\dots\dots [15]$$

and

$$\log.\ r = \frac{1}{\gamma_m} \log.\ r_p \dots\dots\dots\dots\dots\dots [16]$$

VOLUMES OF MAIN AND PUMP CYLINDERS, PER POUND OF AIR ADMITTED.

Main cylinder, $v_2 = r\, v_1 \dots\dots \dots\dots [17]$

Pump cylinder, $v_a = 53{\cdot}15 \frac{\tau_a}{p_a} \dots\dots\dots\dots [18]$

RATIO IN WHICH THE SPACE SWEPT BY THE PUMP PISTON, IS LESS THAN THAT SWEPT BY MAIN PISTON,

$$q_c = \frac{v_a}{v_2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots [19]$$

MEAN FORWARD ABSOLUTE PRESSURES ON MAIN AND PUMP PISTONS.

In the main cylinder where the curve of expansion has for its equation

$$p = \text{constant} \times v^{-\gamma_m}$$

it may be demonstrated by the integral calculus, according to the general method set forth in Rankine, that q_m the ratio of the mean forward pressure p_m to the initial pressure p_1, is given by the formula.

$$q_m = \frac{p_m}{p^1} = \frac{\gamma_m r^{-1} - r^{-\gamma_m}}{\gamma_m - 1} = \frac{\frac{\gamma_m}{r} - \frac{1}{r_p}}{\gamma_m - 1} \dots\dots [20]$$

from which $p_m = q_m\, p \dots\dots [21]$

For the pump, denoting the ratio by q_n, and the mean pressure by p_n, we have in a similar manner,

$$q_n = \frac{p_n}{p_1} = \frac{\frac{\gamma_a}{r_c} - \frac{1}{r_p}}{\gamma_a - 1} \dots\dots [22]$$

and $p_n = q_n\, p_1 \dots\dots [23]$

GROSS WORK IN MAIN CYLINDER.

$$U_m = (p_m - p_a) \times v_2 \dots\dots [24]$$

WORK OF RESISTANCE OF PUMP

$$U_n = (p_n - p_a) \times v_a \dots\dots [25]$$

EFFECTIVE WORK DEVELOPED, PER POUND OF AIR ADMITTED.

$$U_e = U_m - U_n \dots\dots [26]$$

HEAT OF COMBUSTION USED FOR THE SAME, IN FOOT-POUNDS.

$$H_1 = \frac{H}{N} \dots\dots [27]$$

HEAT REJECTED IN EXHAUST, IN FOOT POUNDS.

$$H_2 = H^1 - U_e \dots\dots [28]$$

MEAN EFFECTIVE PRESSURE, OR PRESSURE IN MAIN CYLINDER, EQUIVALENT TO PERFORMANCE OF WORK.

$$P_e = \frac{U_e}{V_2} \dots\dots [29]$$

When given in pounds per square foot, as directly computed from this formula, P_e further represents the effective energy developed per cubic foot swept through by the main piston.

PRESSURE EQUIVALENT TO EXPENDITURE OF HEAT.

$$P_h = \frac{H_1}{V_2} \quad \cdots\cdots\cdots\cdots\cdots\cdots [30]$$

EFFICIENCY OF FLUID.

$$E = \frac{U_e}{H_1} = \frac{P_e}{P_h} \cdots\cdots\cdots\cdots\cdots\cdots [31]$$

This also includes the *efficiency of the furnace,* which for the given form of boiler is unity, because of there being no waste heat up the chimney.

WEIGHT OF FUEL USED, PER EFFECTIVE HORSE POWER PER HOUR.

Since the work performed per pound ot fuel is $N \times U_e$, and there are 1,980,000 foot pounds to be performed by the desired weight C of that fuel, it follows that

$$C = \frac{1{,}980{,}000.}{N \times U_e} = \frac{1{,}980{,}000.}{E \times H.} \cdots\cdots\cdots\cdots [32]$$

The following formulæ were not applied in a majority of the examples, and their deduction is in consequence placed last. They relate to the

DETERMINATION OF THE PRESSURE OR TENSION OF THE STEAM IN THE MIXTURE, AND THE TEMPERATURE TO WHICH IT WOULD HAVE TO BE LOWERED, FOR CONDENSATION TO OCCUR AT THE EXHAUST PRESSURE.

There is first to be found q_d, the ratio of p_s the tension of the steam to p_c that of the air, when thorough mixture has taken place. As long as the steam remains gaseous we have

$$\frac{p_s\ v_s}{\tau_s} = 85\ w_s \qquad \text{and} \qquad \frac{p_c\ v_c}{\tau_c} = 53.15\ w_c$$

Dividing the first of these equations by the second, and noting that $\tau_s = \tau_c =$ the temperature at any point of the expansion of the mixture, we have further

$$\frac{p_s\ v_s}{p\ \ v_c} = \frac{85\ w_s}{53.15\ w_s}, \text{ or } \frac{p_s}{p_c} = \frac{v_c}{v_s} \times \frac{w_s}{w_c} \times \frac{85}{53.15}$$

$$\therefore q_d = \frac{p_s}{p} = \frac{q_w}{q_v} \times \frac{85}{53.15} \cdots\cdots\cdots\cdots [33]$$

To find p for any particular value of p the whole pressure of the mixture, since

$$p = p_s + p_c \qquad \text{and} \qquad p_s = q_d \times p_c$$

$$p_s = q_d\, p - q_d\, p_s \qquad \text{or} \qquad p_s\,(1 + q_d) = q_d\, p.$$

$$\therefore \qquad p_s = \frac{q_d}{1 + q_d} \times p \quad \ldots\ldots\ldots\ldots\ldots\ldots [34]$$

By substituting p_2 for p, in this equation, and calculating the value of p_s, the desired temperature t_d of condensation at the exhaust pressure may be directly found, as being the boiling point corresponding to this fractional pressure.

For the approximate purposes to which this last set of formulæ is here applied, the errors arising from the departure of steam from truly gaseous laws, while closely approaching saturation, may be neglected.

A comparison of t_d with t_2, the exhaust temperature already found on the assumption that all of the steam remained gaseous throughout expansion, will show whether any condensation has occurred, or not, and if so it will enable a judgment to be made as to how far the calculations of work based upon gaseous expansion, are affected.

Owing to the fact of the air tending to cool more rapidly than the steam, while expanding without gain or loss of heat, the latter constantly approaches saturation, and will finally begin to condense if the mixture has not been in the first place sufficiently super-heated for the given ratio of expansion. Formulæ could be deduced to locate on the diagram the exact point at which condensation would first occur, and to calculate the work as measured by the area of the diagram with theoretic precision, but their complexity would not warrant their use, and it will be subsequently seen that in those of the examples following, where the effects of this condensation enter at all, the results of calculations on work and efficiency, though not influenced to any practical degree, will be if anything less than their true values.

The numerical examples, six in number, are now given in tabular form and in the order in which they were originally worked out, as being applicable to the plan of aero-steam engine considered, while working under several conditions, relative to the higher limiting pressures and temperatures, and with varying supplies of air, above the amount necessary for complete combustion. These quantities were chosen to fall within the limits of possible practice, and at the same time to give those results most likely to be applied with advantage to this form of engine.

In the first example given, the temperature t_2 of exhaust was chosen at 212° Fahr. to make a more direct comparison with the common high-pressure steam engine, and the boiler pressure p_1 afterwards calculated, but in the other five, it was found best to place p_1 among the data instead of t_2, the order of all the determinations remaining as in the general formulæ.

The following data are common to all of the examples, and therefore are here introduced, to be referred to when needed.

COMMON DATA.

$P_a = P_2 = 14{\cdot}7$ lbs. per square inch, or $p_a = p_2 = 2116{\cdot}4$ lbs. per square foot.

$H = 10{,}000{,}000$ foot pounds or somewhat less than 13,000 British thermal units, a fair value for good coal whether bituminous or anthracite.

$t_a = 50°$, being roughly assumed as about the average atmospheric temperature in this climate.

$t_f = 100°$ a value that is supposed to be reached by the use of a feed-water heater attached to the exhaust of the engine.

The least quantity of air practically required for the complete combustion of one pound of average coal or coke, was taken at 18 pounds, being about 1·5 times the amount theoretically necessary to furnish the oxygen for combination.

Upon the succeeding page is given the table of examples, arranged as far as possible with reference to compactness. The horizontal row of figures on the top of the table refers to the examples, and the vertical one on the left, to the general formulæ as is there indicated.

The numerical calculations are only carried out so far as to prevent any practically considerable errors from arising. For ratios having values near unity, three places of decimals is considered to be amply sufficient.

The value of g_b, in the third and fifth examples, is caused to come out negative by the fact of t_b exceeding t_1 in which case it should be defined as the ratio of the combined quantities of heat supplied to the steam, both from the fire and the excess of heat of compression, to this latter excess, lost from the air by its fall in temperature from $t_b°$ to $t_1°$

Table of Numerical Calculations on Aero-Steam Engines.

	No. of formula.	Symbol for quantity.	Denomination of quantity.	No. of Example.					
				1	2	3	4	5	6
Data.	....	P_1	above atmos. lbs. sq. in.	32·63	60·	100·	100·	100	60·
	....	t_1	deg. Fahr.	450·	450·	450·	600·	450·	600·
	....	N	lbs.	18·	18·	18·	18·	54·	54·
Results per pound of air admitted.	1	t_b	deg.	256·1	357·9	466·4	466·4	466·4	357·9
	2	r_c	ratio.	2·294	3·172	4·301	4·301	4·301	3·172
	3	t_h	deg.	2864·5	2864·5	2864·5	2864·5	989·6	989·6
	4	t_c	"	3120·6	3222·4	3330·9	3330·9	1456·0	1347·5
	5	q_h	ratio.	13·773	30·102	—175.7	20·440	—61·34	3·088
	6	w_c	lbs.	1·056	1·056	1 056	1·056	1·019	1·019
	7	q_w	ratio.	0·519	0·540	0·561	0·502	0·196	0·137
	8	w_s	lbs.	0·547	0·570	0·592	0·530	0 200	0·140
	9	w_1	"	1·603	1·626	1·648	1·586	1·219	1·159
	10	v_c	cu. ft.	7·106	4·503	2·932	3·418	2·932	5·246
	11	v_s	"	6·218	4·104	2·759	2·897	0·957	1·174
	12	q_v	ratio.	0·875	0·911	0·941	0·848	0·326	0·223
	13	v_1	cu. ft.	13·324	8·607	5·691	6·315	3·889	6·420
	14	γ_m	ratio.	1·349	1·348	1·347	1·349	1·375	1·383
	15	t_2	deg.	212·0	137·9	75·1	162·1	58·8	215·2
	16	r	ratio.	2·380	3·336	4·593	4·584	4·454	3·239
	17	v_2	cu. ft.	31·71	28 71	26·14	28·95	17·32	20·80
	18	v_a	"	12·84	12·84	12·84	12·84	12·84	12·84
	19	q_c	ratio.	0·405	0·447	0·491	0·444	0·741	0·612
	20	g_m	"	0·734	0·596	0·476	0·476	0·482	0·601
	21	p_m	lbs. sq. ft.	5004·9	6410·8	1861·8	7861·8	7960·9	6464·6
	22	q_n	ratio.	0·732	0 606	0·488	0·488	0·488	0·606
	23	p_n	lbs. sq. ft.	4989·3	6518.3	8060·0	8060·0	8060·0	6518·3
	24	U_m	ft. lbs.	91597·	123296·	150179·	166306·	101227·	90429·
	25	U_n	"	36888·	56516·	76310·	76310·	76310·	56516·
	26	U_e	"	54709·	66780·	73869·	89996·	24917·	33913·
	27	H_1	"	555555·	555555·	555555·	555555·	185185·	185185·
	28	H_2	"	500846·	488775·	481686·	465559·	160268.	151272·
	29	P_c	absol. pres. lbs. sq. ft.	1729·2	2326·0	2825·9	3109·1	1438·6	1630·6
	"	"	" " in.	11·98	16·15	19·63	21·59	9·99	11·33
	30	P_h	" " ft.	17520·	19350·	21253.	19192·8	10692·0	8904·4
	31	E	ratio.	0·098	0·120	0·133	0·162	0·135	0·183
	32	C	lbs.	2·011	1·647	1·489	1·222	1·471	1·082

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THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. RICHARDS, Mechanical Engineer.

[Continued from vol. lxviii., page 34.]

Fifth.—Shrinkage, the allowance that has to be made for the contraction of the castings in cooling, in other words, the difference between the size of the pattern and the size of the casting. This is a simple matter apparently, that may be provided for in allowing a certain amount of shrinkage in all directions, but when the inequalities of shrinkage both as to time and degree are taken into account it becomes a problem of no little complication.

Sixth.—Inherent or cooling strains, that may either spring and warp the castings, or weaken them by maintained tension in certain parts, a condition that often requires a disposition of the metal quite different from what the working strains demand.

Seventh.—Draught, the bevel or inclination on the sides of patterns to allow them to be withdrawn from the moulds without dragging or breaking the sand.

Eighth.—Rapping plates, draw plates, and lifting irons for lifting out the patterns. Fallow and match boards, with other details that are peculiar to patterns, and have no counterparts neither in names nor uses outside the foundry.

This makes a statement in brief of what constitutes a knowledge of pattern making, and what must be understood not only by pattern makers but also by any mechanical engineer who undertakes to design machinery, or manage its construction successfully.

As to the manner of cutting out, or planing up the lumber for patterns, and the manner of framing it together, it is useless to devote space to the matter here; one hour's practical observation in a pattern shop and another hour spent in examining different patterns, is worth more to the apprentice than a whole volume written to explain how these last-named operations are performed. A pattern, unless finished with paint or opaque varnish, will show the manner in which the wood is disposed in its construction. The operation of power tools for wood cutting so far as they can be applied in pattern making is easily understood from general principles.

I will therefore proceed to review these conditions or principles in pattern making and casting in a more detailed way furnishing as far as possible the reasons for different modes of constructing patterns, and the various plans of moulding and casting.

In regard to the character or quality of wood patterns, as already stated, they can be made at greater or less expense, and, if necessary, capable of almost any degree of endurance. The writer has recently had occasion to examine patterns that have been used more than two hundred times and are apparently good for an equal amount of use. Such patterns are expensive at the beginning, but .the cheapest in the end, if they are used for a large number of castings. For a special piece, or to be used for a few times, to make such a pattern would be unnecessary and a useless expense, yet with patterns, as with everything else pertaining to machinery, the safest plan is to err on the strong side.

For pullies, gear wheels, or other standard parts that are not likely to be modified or changed, iron patterns are best; wood patterns, for gear wheels and pullies, aside from their liability to spring and warp cannot from the nature of the pieces be made sufficiently strong to withstand foundry use; besides, the greatest accuracy that can be attained by metal patterns is far from producing true castings, especially for tooth wheels. The more perfect the patterns are the less rapping its required to draw them, and the less the rapping the more perfect the castings will be.

The most perfect castings for both gear wheels and pullies are made by drawing the patterns through templates without rapping. These templates are simply plates of metal perforated so that the pattern can be forced through them by screws or levers, leaving the sand intact. Such templates are expensive to begin with, because of the accurate fitting that is required, especially around the teeth of wheels, and the mechanism that is required in drawing the patterns, but when a large number of pieces is to be made from one pattern such as gear wheels or pulleys, the saving of labor is quite enough to pay for the outfit, to say nothing of the saving of metal which often amounts to ten per-cent, and the increased value of the castings which generally exceeds ten per-cent, because of their accuracy.

Mr. Ransome of Ipswich, England, where this template moulding originated, has invented a process of fitting the templates for gear wheels and other irregular forms by pouring melted white metal around the teeth of wheels, which effects a great saving in cost, and answers quite as well as to cut the pattern through to an exact fit in the iron platen.

The plans of moulding a piece in the foundry, or the manner in which patterns are constructed with reference to moulding, is governed by the same conditions that determine the durability and strength of patterns.

The cost of forming a pattern mould is divided between the foundry and the pattern shop. What the pattern maker saves the moulder may lose, and what the pattern maker spends the moulder may save; in other words there is a point beyond which saving in patterns is ballanced by the extra labor and waste in casting, a fact that is not generally realized because of the inaccurate records kept of pattern work and the imperfect records that are generally kept of foundry work. A moulder may cut all the fillets in a mould with a trowel, he may stop off, fill up, and print in to save pattern work, but it is only expedient to do so when it costs very much less than to prepare proper patterns, because much patching and cutting in a mould seldom improves it.

The reader will notice as we go along how everything pertaining to patterns and moulding resolves itself into a matter of judgment in each case, and how difficult it would be to apply general rules.

The arrangement of patterns with reference to having certain parts of castings solid and clean is an important matter, yet one that is comparatively easy to understand. The top of the mould or the cope as it is called, contains the dirt, while the bottom or drag side is generally clean and sound, and the rule is to arrange patterns so that the surfaces to be finished will come on the bottom or drag side.

Supposing the iron in the mould to be in a melted state and to contain as it always must, loose sand and 'scruff,' and that the weight of the dirt is to the melted iron as the weight of cork is to water, it is easy to see where this dirt would lodge and where it would be found in the castings.

Expedients to avoid dirt in castings that are to be finished all over or on two sides are various. Careful moulding to avoid loose sand and washing are the first requisite; sinking heads that rise above the moulds are commonly employed when the castings is of a form that allows the dirt to collect at one point. The moulds for sinking heads are formed by the moulder as a rule, and have nothing to do with the patterns.

The quality of castings are affected by a great many things besides what has been already named, such as the manner of gating or flowing the metal into the moulds, the temperature and quality of the iron, the temperature and character of the mould; things which any skilled foundryman will take pleasure in explaining, in answer to courteous and proper questions.

All these various things pertaining to castings must be understood by the pattern maker, that is, he must know how far his provisions are to meet them, and how far the moulder is to be responsible for the quality of the work produced.

Cores are mainly used for what we may term the displacement of metal in the moulds. There is no clear line of distinction between cores and moulds, as founding is now conducted. Cores may be of green sand and made to surround the exterior of a piece, as well as to make perforations or to form recesses within it. The term "core" in its technical sense means dried moulds, as distinguished from green sand. Wheels for instance, are said to be cast in cores when the mould is made in pieces, and dried. Supporting and venting cores, and their expansion are some of the obscure conditions to which we call the apprentice's attention. When a core is surrounded with hot metal, it gives off from its moisture, and the burning of the 'wash,' a large amount of gas which must have free means of escape. In the arrangement of cores, therefore, attention must be had to some plan of venting, by allowing them to project out through the sides of the mould and communicate with the air.

The apprentice can get a clear idea of this venting process, by examining a tubular core barrel, such as is used in moulding pipes or hollow columns, or by examining large cores about a foundry. Provision of some kind to "carry off the vent," as it is termed, by moulders, will be found in every case.

The venting of moulds is even more important than venting cores because core vents only carry off the gases generated within the core itself, while the gas from its exterior surface, and from the whole mould, has to find means of escaping rapidly when the hot metal enters the mould.

The apprentice will, no doubt, wonder why sand is used for moulding, instead of some more adhesive material like clay. If he is not too fastidious for the experiment, and will apply a lump of damp moulding sand to his mouth and blow his breath through the sand, the query will be solved. If it were not for the porous nature of sand-moulds they would be blown to pieces as soon as the hot metal entered them; not only from the mechanical expansion of the gas, but from its explosion by combustion; the gas jets from moulds, as may be seen at any time in pouring hot metal, will take fire and burn as they issue from the moulds.

If it were not for venting moulds they could be made from plastic material so as to produce finer castings with clear sharp outlines.

The means of supporting cores must be devised, or at least understood by pattern makers, and consist of "prints" and "anchors;" prints are extensions of the cores that project through the casting and extend into the sides of the moulds to be held by the sand and sometimes by the flask; the prints of cores have duplicates on the patterns, which are, or should be, of a different color from the patterns, so as to distinguish them from other parts.

The amount of surface required to support cores is dependent upon their weight, or rather upon their cubic contents, because the weight of a core is but a trifling matter compared to its floating force when surrounded by melted metal. The apprentice in studying the problem of supporting cores must remember that the main force needed is to hold them down, and not to bear their weights. The floating force of a core is as the difference between its weight and that of a solid of metal of the same size, a matter that moulders often forget to consider. It is often impossible, from the nature of castings, to have prints large enough to support the cores, and it is then effected by anchors, pieces of iron that stand like braces between the cores and the flasks, or pieces of iron imbedded in the sand to receive the thrust or strain of the anchors.

A safe rule about cores in constructing patterns, is that whenever a question arises between cored and rib sections, or cored and box patterns is to employ cores. The usual estimate of the difference between the cost of moulding rib and cored sections, as well as of skeleton and cored patterns is wrong. The expense of cores is often balanced by the advantage of having an 'open mould' that is accessible for repairs or facing, and by the greater durability and convenience of the solid patterns.

Taking a column or box frame for machinery that might be made either with a rib or a cored section, as an example, it would seem at first thought that the patterns for a cored column would cost much more by reason of the core boxes, but it must be remembered that in most patterns labor is the principal item of cost, and what is lost in the extra lumber required for a core box or in making a solid pattern, is in many cases more than represented in the difference of labor in favor of the solid pattern.

Cores expand when heated and require an allowance in their dimensions the reverse from patterns: this is especially the case when the cores are made upon iron frames. For cylindrical cores less than six inches diameter, or less than two feet long, the expansion need not be taken into account by the pattern maker, but for large cores it requires careful calculation. The expansion of cores is as the degree of heat they reach, and this is contingent upon the amount of metal that may surround the core and its conducting power.

Shrinkage, or the contraction of castings in cooling is provided for by adding from one tenth to one eighth of an inch to the foot in making patterns; this is a simple matter and is accomplished without trouble by laying down the pattern drawings from the figured dimensions of the finished work, employing a shrink rule that is about one hundredth part longer than the standard scale.

This matter of shrinkage is indeed the only condition in pattern making that is governed by anything like constant rules, and even this sometimes requires to be varied to meet special cases. For small patterns whose dimensions do not exceed one foot in any direction, the rapping will generally make up for shrinkage and no allowance is required in the patterns, but pattern makers are so partial to the rule of shrinkage, as the only constant one in their business, that they are averse to admitting exceptions, and usually keep to the shrink rule for all pieces, whether large or small.

Inherent or cooling strains in castings is much more intricate than shrinkage; it is in fact one of the most uncertain and obscure matters that pattern makers and moulders have to contend with. Inherent strains that may weaken castings or cause them to break while cooling, or sometimes even after they are finished, must in many kinds of work be carefully considered, both in the preparation of designs and the arrangement of patterns, especially for wheels and pullies that have spokes, and in struts or braces that have both ends fixed.

The main consideration connected with cooling strains however, is that of the castings being warped and sprung; this difficulty is continually present in the foundry and machine shop, and there is perhaps no question in the whole range of mechanical manipulation about which people will differ more than as to the means to prevent the springing of castings. This being the case the apprentice can hardly hope for much information here, yet there is no doubt but what the springing and strains in casting are the result of constant causes and principles that might be fully understood if it were not for the ever changing conditions that exist in casting both as to the form of the piece and the temperature and quality of the metal that is used.

Springing and warping of castings is the result of unequal strains, caused by one part cooling or "setting" sooner than another. Thus far all seems clear, but the next step takes us into the dark. What produces irregular cooling and how is it to be avoided? These are the questions that must be dealt with to secure true castings.

Irregularity of cooling may be the result of unequal conducting power in different parts of the mould or cores, or it may be from the varying dimensions of the castings which contain heat as the thickness, and give it off in the same ratio.

As a rule, the drag or bottom side of a casting cools first, especially if the mould rests on the earth and there is not much sand between the castings and the earth. This is a common cause of unequal cooling, especially in large flat pieces. The air being a bad conductor of heat and the sand usually thin on the cope side and the sides protected by the flask, the result is that the top of moulds becomes quite hot, while at the bottom the earth being a good conductor, carries off the heat and cools that side first, so that the iron 'sets' first on the bottom and then cools and shortens on the top, causing convexity on the underside.

This is but one out of many influences that tend to irregular cooling and is described with a view of giving the apprentice a clue from which to search for others.

The want of uniformity in sections which produces irregular cooling can be avoided by a disposition of the metal to meet it. This, so far as the extra metal that has to be used to balance castings is a waste that engineers are loath to consent to, and seldom recognize in their designs for moulded parts; yet the difficulty of irregular cooling can be in a large degree met by a proper distribution of the metal without wasting it to balance strains, if the matter is understood by the engineer. No one is prepared to make designs for castings who has not studied the subject of cooling strains as thoroughly as possible by practical examples as well as from theoretical deductions.

The quality of the metal, the temperature at which it is poured and the manner of gateing, all have to do with the truth of castings, but the space here will not allow the subject of moulding to be noticed farther.

Draught, or the taper required to allow patterns to be drawn readily is another of those indefinite conditions in pattern making that must be constantly a question of judgment and experience. It is not uncommon to find rules for the draught of patterns laid down in books, but it would be difficult to find any such rules applied. The draught may be one sixteenth of an inch to each foot of depth, or it may be one inch to a foot of depth or there may be no draught whatever. Any rule considered aside from specified conditions would only confuse a learner. The only plan to understand the proper amount of draught for patterns is to study the matter in connection with the patterns and the foundry.

Patterns that are deep and for castings that require to be parallel or square when finished, are made with the least possible amount of draught. If a pattern is a plain form that affords facilities for lifting or drawing, it may be drawn without taper, if its sides are smooth and well finished. Pieces that are shallow and moulded often should, as a matter of convenience, have as much taper as possible, and as the quantity of taper can be as the depth of a pattern, we frequently see them made with a taper that exceeds one inch to the foot of depth.

Moulders generally rap patterns as much as they will stand, often more than they will stand, and in providing for draft it is necessary to take these customs into account; there is no use in making provision to save rapping unless the rapping is omitted.

Rapping plates, draw irons and other details of pattern making are soon understood by observations. Perhaps the most useful suggestion I can offer is to say that draw irons should be set on the under side, or the bottom of patterns instead of on the top where they are generally placed. A draw plate set in this way with a hole bored through the pattern so as to insert the draw-irons from the top, cannot pull off, which it is sure to do if set on the top side.

Every pattern should be ironed with dowel pins, draw and rapping plates, no matter how small the pattern is, unless it is some trifling piece. If a system of draw irons is not rigidly carried out, moulders will not trouble themselves to take care of patterns.

In conclusion I will say on the subject of patterns and castings that the learner must depend mainly upon what he can see and what is explained to him in the pattern shop and foundry. He need never fear an uncivil answer to a proper question applied at the right time and place; mechanics who have enough knowledge to impart useful information about their business have invariably the courtesy and good sense to impart such information to those who require it.

The apprentice should never ask questions about simple and obvious matters, or about such things as he can easily learn by his own efforts. The more difficult a question is, the more pleasure a skilled man will take in answering it ; in short, let the apprentice consider his questions before asking them; a good plan is to write them down, and when he wants information about casting, never go to the foundry to interrupt a manager or moulder at melting time, nor in the morning when no one wants to be annoyed with questions.

I will, in connection with this subject of patterns and castings, suggest a plan of learning that is especially applicable in this case—that of adapting the habit of imagining the manner of moulding, and the kind of pattern used in producing each casting that comes under notice.

Such a habit soon becomes easy and natural in a short time, and is a sure means of acquiring an extended knowledge of patterns and moulding.

A pattern maker no sooner sees a casting than he imagines the kind of pattern used in moulding it. A moulder would imagine the plan of moulding and casting it, while an engineer will criticise the proportions and think of the strains upon which they are based, and how much skill was brought to bear in making the original designs. The engineer will also imagine the moulding and castings of a casting so far as affected by its designs and if skilled as he ought to be, will detect at a glance any useless cost of patterns or expense in moulding.

To be continued.

Birmingham Steel Pens.—The number of steel pens made in Birmingham per week is 9,800 gross, or 14,112,000 pens. Twenty years ago, Birmingham pens sold at 5 shillings ($1\frac{1}{4}$ dollars) the gross; to-day the best pens are sold at three cents the gross. If we consider that in a gross there are 144 separate pieces of steel and that each of these pieces passes through twelve hands before becoming a perfect pen, the fact that these 144 pens are furnished for three cents after having paid for the material, paid the wages of the workmen and yielded a paying profit, is one of the most convincing demonstrations of the value of the results obtained by the employment of machinery and the division of labor.

Chemistry, Physics, Technology, etc.

THE EXTERNAL ASPECTS OF THE SUN—ITS PHOTOSPHERE AND SPOTS—ITS CHROMOSPHERE AND CORONA.

By Professor S. P. Langley.*

If any one were called on for a description of the earth on which we live, with all its lands and waters, it would be well understood that the task was a heavy one, and that even an abstract of such a theme might occupy days of discourse. But the subject of the Sun is, if anything, still more extensive, and you will, I am sure, understand that in taking it as a topic of a single lecture, I have no pretension to do more than to epitomize a part of our knowledge.

The tendency to divide research has been felt here as elsewhere. Even in astronomy we have specialties within specialties, and among observers, giving much attention to the Sun, some who devote their time to studying the laws of the motion of the spots, some to those of the emission of its light and heat, some to investigations with the aid of spectrum analysis, and many more subdivisions of labor beside; and since, if we attempt an allusion to all these topics, an hour would give time only to read, as it were, the headings of the chapters of our knowledge, I prefer to take one of these chapters by itself, and to speak to-night chiefly of the external aspects of the Sun, of the sources of our knowledge of it, and of the things which come in such connection.

To do this, since I cannot take you to an observatory, I have brought here one or two of the instruments by which such research is actually carried on. I cannot bring the Sun, but I can bring some pictures of it, certainly authentic, since the Sun himself made them, and I will try to project them on this screen, so that all may see. Before doing so however, let us look a moment at this little representation of the Sun, as if at a sort of outline map of an unknown region we are going to explore.

[The Lecturer pointed to a representation of the Sun and Corona, suspended near the front of the stage.]

THE PHOTOSPHERE.

This circle represents the Photosphere of the Sun, the photosphere being simply what its name implies, the sphere of light, or in other words, the Sun's visible surface and what we see daily with the naked eye. Outside this is a thin envelope, rising here and there into irregular prominences. This is the Chromosphere, the color sphere, a thin shell of crimson and scarlet tint, invisible even to the telescope, except at the time of a total eclipse, when alone its true color is discernible, but seen exactly as to its form, at all times by the spectroscope. Outside of all this is this strange shape which represents the still mysterious "Corona," invisible as yet to the spectroscope. There are other subdivisions of which I do not speak, but let us carry in our minds the three main divisions, the Photosphere—or visible surface of the Sun, within which lies nearly all its mass—the Chromosphere, and the Corona; the latter being very faint and unsubstantial, but as to size enormous and larger than all the rest.

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*[A Lecture delivered in Pittsburgh, April 21st, 1874.]

Almost everything in practical astronomy resolves itself into a measurement of some sort and a subsequent computation, for it is a science which especially deals with the greater works of that Power which made all things by number, weight and measure.

Measurements of precision therefore are at the foundation of all sound astronomical knowledge, and these in the case of the Sun, are largely carried on by the Position Filar Micrometer, the little instrument before me. [Instrument exhibited.]

It consists here essentially of a screw whose threads are so fine that there are one hundred of them in an inch. One complete turn of the screw then advances its point 1-100 of an inch. It has a very large circular head, whose circumference is itself divided into sixty parts, so that we can reckon one sixtieth part of a turn, or a motion of 1-6,000 part of an inch. We can in fact do much more, the 1-60,000 part of an inch being customarily reckoned in practice. Now to observe these small motions, we use high magnifying powers, and to obtain a pointer delicate enough, we take commonly threads from the cocoon of the little spider which builds in decayed wood and which are far finer than those of a cobweb. Since they would be invisible to you, I have replaced them for this occasion, by fibres of raw silk; but I will continue to speak of them as the "web." The "web" then is attached to sliding frames moved by the screw, so that the heads can be made to approach or recede from each other.

THE MICROMETER.

[The micrometer was now placed so that its eye piece projected the image of the "web," illuminated by the lime light, upon a large screen near the back of the stage.]

You see them now upon the screen, (Fig. 1.) where they look as large as ropes. To give an idea of their real size, I put a cambric needle beside them.

[This magnified image of the head of the needle was thrown on the screen with the web.*]

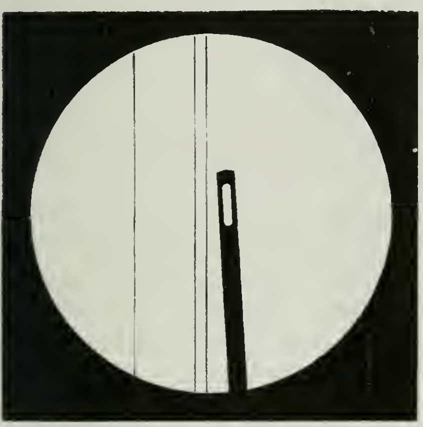

Fig. 1.

You see that the middle thread looks larger than the others. This is because two threads are there placed nearly in line. To show how they pass each other, and how they are controlled, I now move one of them through the space of 1-200th of an inch. Those who are nearest see that they have separated, and that the light appears between them. I move them through 1-50th of an inch and the change is, I hope, now visible to the most distant spectator. Such is one part of the means of celestial measurement, for though we cannot apply these threads directly to the Sun, we can place the micrometer in the telescope just where the image of the Sun is formed and measure that.

But here a new difficulty arises. The large lens at the end of the telescope, which forms the image, necessarily acts as a burning glass, and concentrates both light and heat there in an intolerable degree. That of the equatorial at Allegheny is 13 inches in diameter, and when its heat is concentrated by the proper lenses, it is intense enough to melt iron, and its light is increased in proportion. Now the eye must somehow rest on the image of the Sun in spite of the intolerable brilliance and heat, and the old observers used to look when the luminary was hidden by clouds, though afterwards colored glasses were used. Sir William Herschel used glass cells filled with diluted ink, to shield the eye, but these and other such contrivances have been lately discarded in favor of an apparatus which does not interpose any dark or colored screen, and yet cuts off all the light and heat we wish to dispense with.

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*We are indebted for the wood-cuts which illustrate this lecture, to the courtesy of the Pittsburgh *Evening Telegraph*.—Ed.

THE POLARIZING EYE-PIECE.

This is the Polarizing Eye-piece, an instrument which has lately been independently invented by several observers as their needs called for it. The instrument before you is the embodiment of an idea which occurred to me long since, and which, some four years ago, the liberality of a citizen of Pittsburgh to the Allegheny observatory, enabled me to have executed for its use. It is constructed especially for the telescope, and is not adapted for lecture experiment; but here is another example of the same principle, which will enable me to illustrate its action. In each of these two little tubes there is a perfectly transparent substance, as you see, when I place them successively before the lantern, by their transmitting its light so as to form a bright circle on the screen. According to all common experience, we might suppose that since either taken singly is transparent, they would be so taken together, and that when I place them both before the lantern, its light would pass through both, and fall on the screen as before. But you see that this is not necessarily so, and that when united, they become as it were, opaque or transparent at pleasure. Now the beam is evidently passing through both, and now while both still remain in a position to let it pass, as I turn one of them, you see the light fade and disappear. It is just as though on turning one of the sashes in a double window upside down, we found that we could not see through the window at all, the panes becoming opaque as a mill-stone in the reversed position, and transmitting more and more light as we turned them upright again. As I turn this over, you see the light waning just as though the brilliant flame behind it were dying out; now you can scarcely see the outline of the circle on the screen, now it is gone, and at a touch it shines out again. This is due to the polarization of the light, and with the Polarizing Eye-piece which I now hold up before you, and which is constructed on a similar principle, I have studied the Sun for years, at times keeping my eye gazing for four or five consecutive hours at the details of its surface without injury or fatigue.*

PHOTOGRAPHY.

This is one means of the study of the Sun, but another and most important one is photography. Great difficulties have been found in photographing the Sun; one, of course, being the intensity of light, and in this case the evil has been avoided by an extremely brief exposure. All of us know what a tedious minute we pass while sitting for our photograph. The Sun's portrait is more quickly taken, a special arrangement reducing the time in his case to 1-150th of a second, and even less I believe would do. After the telescope, these—with the spectroscope, which is not included in our present subject,—are the principal sources of our modern knowledge of the Sun.

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*For a description of this Instrument, see this Journal, Vol. xci. No. 541, p. 115.

Let us before exhibiting the results of this knowledge, briefly review the steps of discovery which lead to it. The ancient philosophy which held possession of men's minds from the time of Aristotle to the seventeenth century of the Christian Era, represented the Sun figuratively as "the Eye of the Universe," and literally as an orb of pure flame supported in a sphere of crystal; and few of the first discoveries of the telescope were received with more incredulity by the old school, than those of the spots on the Sun. "For some time, indeed," says Mr. Proctor, "the possibility of their existence was earnestly denied by the students of the Aristotelian philosophy. 'It is impossible,' they gravely urged, 'that the Eye of the Universe should suffer from ophthalmia."

But the existence of spots on the Sun was confirmed, and we who hear of them as of a familiar thing, can hardly understand the interest the discovery caused, the contention it aroused, and the blow to the ancient philosophy it dealt. Almost simultaneously with the discovery of the spots, it was observed by their motion that the Sun was rotating, but when it was subsequently tried to ascertain the exact time of the rotation, the most perplexingly contradictory results were obtained, and no two observers could agree on the time it took the Sun to revolve. Galileo made the period of the Sun's true revolution to be a little over 26 days; Scheiner, between 26 and 27 days; Flamsteed, 25 days and a quarter; Cassini III. 25 days and 14 hours; Lalande, 25 days and 10 hours; and thus every one found a different value. Delambre who examined and reduced a great number of observations, obtained from them something like thirty different values! He concludes that the task of finding the true time of the Sun's rotation is hopeless, and this leads him to the remark that it is a problem which every astronomer should try once in his life, and *only* once; and what is strange, he does not seem to think that these surprising differences have in them anything especially curious. Yet these enormous discrepancies were particularly strange anomalies in a science so exact as astronomy, which had even in the last century succeeded in determining the time of rotation of so relatively insignificant an object as

Mars within a few seconds. These singular discrepancies have since been explained and their cause, when discovered, threw great light on the real nature of the Sun's constitution.

It should be mentioned that an early idea had been that the spots were mountain tops or islands rising out of a fiery ocean, but that Wilson of Glasgow, in the last century advanced the opinion that they must be depressions not elevations. A spot as we shall presently see is composed of two principal divisions, a faint outer shade called the Penumbra, and a darker inner one, the Umbra, and it is easy to see that if the spot be a saucer shaped depression, in which the Penumbra is represented by the sloping sides and the Umbra by the bottom, that then, as it is approaching the edge and turned side-wise to us, the further side of the Penumbra will appear broad, and the nearer be foreshadowed, as it appears in this conventional illustration on the screen. (Illustration shown.)

The observation may appear easy; it is however very uncertain in practice, owing to the rapid changes of form the spots undergo, and the apparent tremor of the Sun's edge, due to the movements of our own atmosphere. Our entire confidence that the spots are really depressions, rests on other grounds, and is largely due to a skillful discussion of Mr. Carrington's observations by M. Faye; who has conclusively shown not only that such is the case, but that an approximate estimate of the depth of the cavity is attainable. Wilson's observation, however, led the way to a celebrated hypothesis of Sir William Herschel's, who toward the close of the last century, having considered the *facts* of an apparently dark nucleus, a light Penumbra and a brilliant photosphere, suggested that the light and heat of the Sun *might* come from an outer layer of brilliant clouds, and that the interior might be a dark and solid globe completely protected by an intermediate stratum of cloud from the outer heat, and that it might be conceivably habitable by beings like ourselves.

There are, you see, two distinct things: First the facts, second the hypothesis; but people are very apt to confound them. Herschel's views got adopted into the text-books in a more or less distorted shape and have formed the almost exclusive basis of popular instruction on this subject for the last eighty years.

Most of us who remember our own school lessons, can recollect being taught that the Sun was a solid globe, really dark, but surrounded by a sort of brilliant atmosphere, which was all we saw of it except when a rent in the outer brightness enabled us to discover a little of the dark interior which formed the spot.

This was what we were ourselves very generally taught, and such things still remain in school books. But now, let us consider what has been found of late years, with relation to that singular fact that no exact period of rotation could be determined for the Sun. When the cause of the anomaly was discovered, it cleared our views on the nature of the Sun a good deal, as the Sun, it appeared, had no single time of rotation. Different parts required different times to rotate, a part near the solar equator not merely moving faster in miles, but making more turns about the axis in a given time, than a portion near the solar pole. Now, of course, in a solid globe, this would be impossible, and it is an irresistible conclusion that a globe whose parts revolve at different rates, and consequently with a motion on one another must be mainly liquid or gaseous.

This is quite different from what we used to be taught, but while I agree that our knowledge is not absolute, it is safe to say that though liquids and even solids may conceivably exist on the Sun, we have almost conclusive reason to believe that it is principally a gaseous or vaporous body. I have so often heard it asked how the Sun can be gaseous and yet possess the enormous mass which enables its attraction to hold this distant earth in its orbit, that I think there must be, commonly, some confusion of thought on this subject, even among the cultivated and intelligent. If to any such what I have just said cause a difficulty, the simple suggestion that a pound is equally a pound whether of gas or lead may help to remove it, and any one who wishes to realize what an enormous weight we obtain from the lightest gas, in taking enough of it, may observe that while a cubic foot of hydrogen (the lightest gas known,) weighs but about the tenth of an ounce, a cubic mile of it weighs 347,000 tons.

But we have been talking a long time about the Sun, without seeing it, and I now introduce you not to any engraving or drawing of it, but to its own autographic portrait, self-impressed, so to speak, in the transparent picture, from the fine photographs of Mr. Rutherford, which I throw on the screen.

[Three successive photographs of the Sun and spots were now exhibited, each forming a circle of about ten feet in diameter.]

Let me call your attention to the remarkable perfection of the photographs, not only the spots, but the Faculæ and minor details being shown. We see before us a faithful image of the great globe of light, whose dimensions I could easily state in miles, but which, when we hear them, we cannot be said to comprehend. Who comprehends, for instance, the vastness of the world in which we live? Yet, here is a circle of just the proportionate size of our own globe, which I hold on the screen beside the Sun.

[The small circle in square Fig. 2 shows comparative size of the earth.]

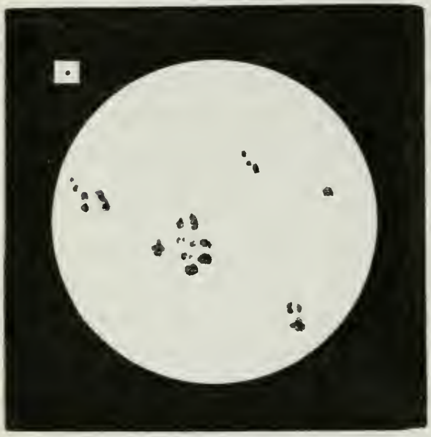


Fig. 2. **The Sun, September 20th, 1870.**

And if we cannot "realize" a diameter of 8,000 miles, how can we adequately conceive one of more than a hundred times that? Perhaps it will help us to the conception of this enormousness to recollect that the moon which seems so far from us, and a neighbor to the stars, is 240,000 miles distant, while the Sun's diameter is 860,000 miles. If then, the Sun were made hollow, the earth might be placed at its centre, and the moon go on revolving at her present distance, her entire orbit lying within this imaginary hollow sphere, and with several hundred thousand miles to spare. We see the large spot here as it appeared on the 20th of September, 1870, near the eastern side of the Sun.

What we know most certainly about the spots, is their enormous dimensions (obtained by methods I will try to show presently,) that they are depressions, and that they are not permanent in form or position. That is, they not only turn *with* the Sun, but have a drifting motion *on* it, and grow and change shape and disappear as they move; some living only for days, some for months. They are found almost solely in two zones, one to the north of the Solar Equator, and one to the south of it, and, though we cannot yet predict of any particular one, when it will appear, or how long it will live, we know that the spots, as a whole, have their times of maximum and minimum, or, in other words, that the Sun has periodical epochs for being covered with spots, and others for being nearly vacant of them; the period of the minimum coming considerably more than one-half the way from one maximum to another. A further very curious fact which was elucidated by Mr. Carrington, is that the frequency of the spots is in some way related to their position on the surface, as when they are rare, those which appear lie nearer the equator than the majority do in years when they are plenty; while Messrs. De la Rue, Stewart and Loewy have shown that in times of violent solar disturbance the excess of Sun-spot area changes from the Northern to the Southern Hemisphere, and vice versa in about the time of one revolution.

This photograph was taken very near the maximum period, which occurs every ten or eleven years. These brighter portions near the edge are called faculæ, and all over the surface are mottlings.

Look well at the immense size of this spot, (it was visible to the naked eye,) and if I say that its surface is largely composed of metals turned into vapor by the intense heat, you will be prepared to hear me add that the earth on which we live, our great globe itself might be dropped into the chasm of this Umbra without touching the sides, but that this whole world of ours would be dissipated in vapor if it fell into the Sun, as a snow-flake in falling into a furnace. This seems exaggeration, perhaps. It is sober truth, no metaphor is likely to exaggerate the tremendous size—the awful power of the Sun. I hold, for instance, the drawing representing the earth, up against the Umbra of the spot, and you see that there is literally room for the earth to drop into the gulf without touching either edge. You will observe the positions of the spots here, and then in these other two photographs of September 22 and 26, which will afford an idea both of the motions of the spots in themselves, and of the changes in their appearance from the solar rotation.

Now, we naturally wish to know what exists in this immense spot; for doubtless if we could get near enough to the Sun we should see that there were all kinds of curious details to be discovered in that unknown region. But owing to various causes solar photographs cannot be magnified so as to show much detail. Mr. Rutherford's, which we have just seen, are confessedly the best ever obtained, either in this country or in Europe—even these, however, gain nothing by further magnifying, but become dim and unsatisfactory when so treated.

Here is one where a small part of the Sun containing a spot has been taken and greatly enlarged, so as to cover the whole screen, but there is nothing new told us about the spot. It is large but also vague and blurred, and tells us nothing we did not see in the small scale. I may use it however to illustrate the way in which the spots are measured. You see the wires of the micrometer projected on the screen beside the spot. As I turn the screw, the wires move while the side remains still, and now the image of one wire just touches the eastern side of the image of the spot, and that of the other, the western. It is not a large one, and on reading the micrometer head I find that the wires are actually one-twentieth of an inch apart, while the size of the whole Sun, in the photograph which is being magnified, is (let us say) two inches. It is easy to see then, that the length of the spot is one–fortieth of the Sun's diameter, which is 860,000 miles, and a simple division shows the spot to be 21,500 miles long. The width of the spot can be measured in the same way, its irregular boundary traced, and its area calculated as a surveyor does that of a field. I have used approximate numbers, and have omitted some operations needed in practice, which however do not affect the principle of the method of such measurements, which is, as you see, quite simple.

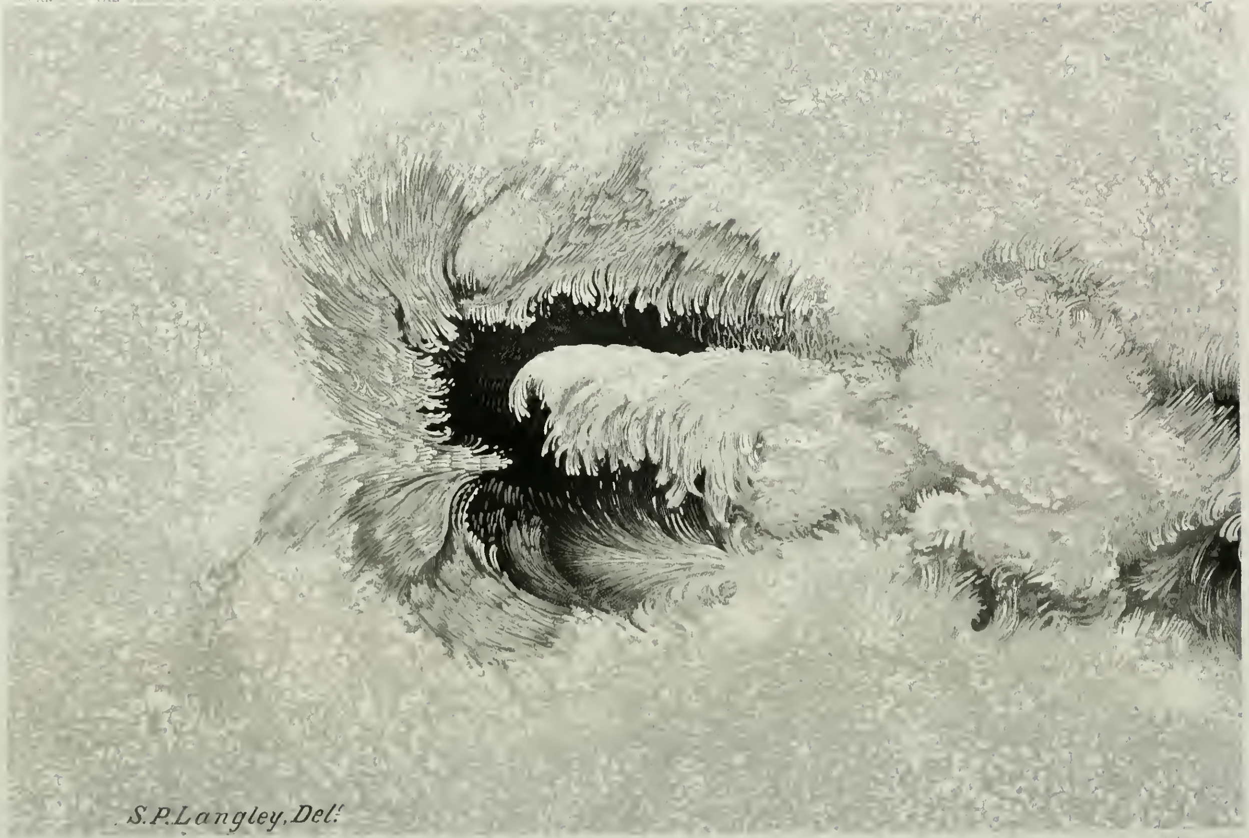
I called your attention however to the fact, that we cannot suppose this vast space to have nothing in it. Such vast dimensions in a world so like ours, must, we anticipate, be filled with curious things, if we could but get to see them, and several observers, myself among the number, have given particular attention to find out what is really there.

The difficulties are very great, but they have been partly overcome, and I wish to next show you the partial results of the labors conducted in this direction at the Allegheny Observatory in the drawings which I will now throw upon the screen.

We now have a greatly more magnified view than before, and yet you see it is not blurred by magnifying, but full of detail. We have been brought quite near to the Sun, as it were, and we can now see here for ourselves, much what till lately has been thought out of the reach of observers.

The surface of the Sun away from the spot is filled with minute white forms apparently floating in an ocean of comparatively gray fluid. The most accurate representation of them which I know in print, is in an illustration from a sketch by Huggins, given in Mr. Proctor's well known excellent work on the Sun; where will also be found a full statement of all our knowledge about them up to a very recent period.

These things, which were first noticed about ten years since, though covering in their united area but a small portion of the Sun's surface, are the principal sources of his light. These were considered most mysterious things when first discovered, and an eminent astron-


S.P.Langley, Del.

A TYPICAL SUN-SPOT

omer even went so far as to suggest that they might be individual organisms. I have lately, however, been able to resolve them into smaller bodies, and while their exact nature is still undetermined, I think we may venture to speak of them as a very peculiar kind of clouds, composed, not of the vapor of water like ours, but chiefly of the vapors of iron and other metals volatilized by the intense heat; clouds which may precipitate their suspended contents as ours do rain or hail, but in a rain of molten metal, and differing from our clouds besides this in a tendency to filamentary structure, in a peculiar tenacity of form, and (conceivably) in their union of some of the properties of liquid and gaseous matter in the same substance.

You see the penumbra which appeared in the enlarged photograph, like diffuse mist, is in reality diversified by innumerable filaments, which seem like the long floating grasses bent by the whirls and eddies of a stream; but we must remember that the scale of action is here enormous, that the objects compared to blades of grass, are each thousands of miles long, and the whirls are immense cyclones moving with inconceivable velocity. We may properly call it inconceivable, for though we can measure and number, we cannot realize it. A terrestial cyclone which destroys ships and houses, is compared with this a sluggish breeze, for our tropical cyclone moves 50 to 100 miles an hour, while these demonstrably move 50 to 100 miles a *second*, as Young and others have shown.

The heat too is beyond comparison greater than that of the Simoon or any wind that sweeps over the great African desert, for the gale is here, as we shall presently see, far hotter than the air which has been forced through the glowing bed of a blast furnace.

Here is another spot, and its appearance like that of the first, is oddly suggestive of cold rather than of heat. The same sort of impression is sometimes received in looking through the open doors of a puddling furnace, at the snow-white metal. It is due here, I suppose, to the whiteness and crystal-like forms, but is of course wholly an illusion. [Reproduced in Plate I.]

Notice the curves in which the filaments sweep down to the edge of the Umbra; the really complex structure of the Umbra itself; the masses of photospheric matter islanded in the penumbra of the spot; the variety of the forms it includes; and the extremely fine subdivision of portions of the filamentary structure.

In one part is an extraordinarily symmetrical figure in which numberless fibres are disposed in nearly parallel curves, in which they lie on each side of a central axis, with almost the regularity of a sculptured ornament. This regularity, in the present instance, is a careful transcript from nature, but yet it is quite unusual, and it is very difficult to account for the balanced symmetry of the disposition of the fibres, in the plume-like form to which I have just called attention, as compared with their irregularity in other and adjacent portions.

Before taking leave of the spot, to give an idea of its size, I will place on the screen beside it an outline of the State of Pennsylvania, drawn on the same scale as the projection.

To be continued.

RESEARCHES ON THE TEXTURE OF IRON.

By M. Janoyer, C. E., Metallurgist.

(Translated from the *Annales des Mines*, Vol. 5. p. 90, 1874.)

During the last fifty years, siderurgy, or the metallurgy of iron, has been enriched by a host of discoveries. New methods have been adopted in practice, old ones have been materially modified, and a large number of treatises have been written, intended to contain all the knowledge thus obtained. The art of iron-making has been raised to the dignity of a true science, though, like all the other sciences of observation, it is yet far from complete.

It is a natural assumption, that the intimate nature of a metal as important as iron, would be very perfectly known; but those metallurgists who have devoted themselves to its serious study, have not been long in perceiving that a vast field for observation still remains unexplored; and that too, in a great many directions where the subject seemed to be entirely exhausted.

The texture of iron, which is the object of this memoir, is one of those delicate questions, on which we are very willing to believe that all has been said that can be, because its study is, at least in appearsince, one of the greatest simplicity. An experience of many years however, confirmed by numerous experiments, and strengthened by various interesting communications from others, has led me to recognize the fact that the ideas upon this subject which are at present in vogue, do not at all meet the requirements of science, and that, consequently, what is commonly accepted concerning the grain of iron, must be, in great part, materially modified.

From the time of Bergmann, of Hassenfratz, and of Karsten, down to the present day, a very complete polymorphism has been given to iron, because of the want of a more exact knowledge of the causes of the various aspects under which it is presented to us in the arts.

Thus, as a result of incomplete observation, irons have been classified as granular, fibrous, and mixed granular and fibrous. And moreover, inasmuch as, from certain ores, it was easier to produce a fibrous than a granular iron, or the reverse, many metallurgists have regarded this tendency as inherent in the ore itself. Consequently such an ore is reputed to yield always fibrous iron, and such another, always granular iron.

I shall, in these pages, attempt to demonstrate that this so-called tendency to such and such a texture is not inherent in anything, and that iron is not a polymorphous body, as has been asserted by Hassenfratz and by Bergmann.

As I have already maintained,* iron presents but a single texture, and that the granular one; all others are only metamorphoses of this, due to defective temperature at the moment of finishing, which does not permit complete welding of the entire mass. Since, therefore, the grain of the iron depends only upon its more or less perfect welding, it seems to me more rational to base the classification of irons upon their weldability, of which granulations and fibres are only the effects.

Without desiring to substitute, at once, my classification into welded, non-welded, and imperfectly welded, irons, for the classification into granular and fibrous irons, which has become firmly fixed by time and use, I believe it necessary nevertheless, to regard the term granular iron as the designation of an iron perfectly welded throughout, and fibrous iron as that of a non-welded iron. The fact here embodied, now well understood and thoroughly established, is sufficient of itself to throw a flood of light upon many of the properties of iron, until now incompletely studied. Here too, we find the explanation of many of the assertions of Karsten and of other distinguished metallurgists, such as: "Soft iron becomes fibrous sooner than hard iron;" "Iron in large bars never exhibits fibres," etc. This view of the case, moreover, must be the means of correcting many popular errors: errors, too, which perpetuate themselves constantly without check, such as: "A facetted fracture, more or less course, is always the sign of a bad iron;" "A badly refined iron is recognizable at once by the facets intermingled with its fibres," etc.

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* *Annales des Mines*, xv., 1859.

The proofs which are to be urged in support of this new method of viewing irons, are very numerous. They are to be found:

1. In the different methods of manufacture.
2. In the study of iron under the microscope.
3. In the physical properties of this metal.
4. In the well established influence which certain metalloids have upon its quality.

I. PROOFS DRAWN FROM THE DIFFERENT MODES OF MANUFACTURE.

Charcoal-refined iron, that is, iron manufactured exclusively with fuel of immediate vegetable origin, and which is the purest iron known to commerce, always presents a granular texture. I will say with Karsten,* "When iron is very pure, its texture is granular," but I would add homogeneity to this and say that when iron is very pure and very homogeneous, its texture is granular.

Sometimes persons are found who think that the grain of iron is due to the hammering, that powerful means of compressing the molecules together; and that from this compression, the granular condition necessarily results. This deduction, however, is drawn only from the granular aspect presented by hammered iron compared with that of rolled iron, which latter is always more or less fibrous.

Without denying this action of the hammer, which, especially in the cold, produces in iron brilliant plane facets—which are not however, due to the inherent grain of the metal, as I shall show further on—I maintain that the grain of the iron is due, essentially, to the high temperature which exists during the last two operations; a temperature which permits the complete expulsion of the cinder and the perfect welding of the entire mass.

During the "breaking up," the refiner causes to pass before the tuyere, in the oxydizing region, all the iron, which, under the influence there present, falls piece by piece, as it were entirely melted, upon the mass beneath, the very fluid slag produced under these circumstances, favoring the operation of sealing and the perfection of the welding. This last operation, moreover, is assisted by the pressure exerted upon the mass by the workman, by means of his long rod which he uses as a lever to condense it, making a fulcrum of the furnace wall. In

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**Manual of Metallurgy*, i, 58.

order to prove that the welding has been perfect, the refinery ball, after shingling, may be cut across. It will be seen at once how perfectly homogeneous and compact it is; a character entirely distinct, in these respects, from that of the ball from the puddling furnace.

The temperature at which, upon these hearths, the mass of iron has been produced, is sometimes so high that the workmen are obliged to allow it to cool a little before shingling, in order that it may not be broken in fragments under the hammer. This slight cooling, which would be a serious fault in working a puddled mass, because of the enormous quantity of cinder to be expelled, is not at all injurious to the ball from the charcoal low refining hearth. The mass has already, in the operation of refining, been completely welded together.

Puddled iron, unlike charcoal refined iron, presents quite frequently a fibrous texture. On comparing together the two processes of manufacture, it is easy to see that the temperature in the puddling furnace, is very much lower. Again, the operation of puddling consists in stirring a mass of spongy iron in the midst of a bath of cinder, which prevents the intimate approximation of its particles. Both these causes oppose the thorough welding of the mass, and consequently favor the production of a fibrous texture; since during the subsequent working, the molecules can slide over each other, thus giving to the iron its fibrous appearance.

But, it may be said, good granular iron is produced by the puddling furnace; one may easily convince himself of that fact, by a glance at the beautiful products which are turned out every day from the iron works of the Loire, such as tyres, axles, etc. And it is to the puddling too, that we owe the excellent qualities of that iron, now so much in demand. We reply, yes, it is puddling; but it is a very different process from that in use in the large English mills, and by which is made the ordinary bar iron of commerce. The difference, too, is an essential one; it is based upon the precise high temperature employed in working the granular iron, and upon a prompt hammering by which consequently, a more complete expulsion of the slag is effected, and a more perfect welding of the mass secured.

In the description which I have given* of the manufacture of granular iron, I have insisted upon the high temperature necessary for the production of this iron. I have called the attention of manufacturers to the means to be employed in order to obtain it, especially during the second period, that immediately preceding the formation of the balls.

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* *Annales des Mines*, XV, 147.

Under this high temperature, which is an absolute *sine qua non*, the intimate approximation of the molecules of the iron is facilitated by the separation of the slag. I also recommend strongly, what every one who has had to make granular iron knows well, the prompt transference of the ball from the furnace to the hammer, in order that it may not have time to cool so far as to interfere with the expulsion of the slag and the welding of the metal. In order to render more palpable what I have just said upon the causes which make the distinction between granular and fibrous iron, in its manufacture, let the experiment be tried of lowering the dampers of the furnace at the moment when the puddler is ready to make up his charge into balls of granular iron, thus lowering the temperature; and then let these balls be rolled in the slag which is resting upon the hearth and carried at once, in this condition, to the hammer. These balls will now yield, when drawn out, iron entirely fibrous.

Here the puddling process itself has not been modified, and yet the iron which was granular has become fibrous. Lowering of the temperature, which has favored an incomplete welding and the distribution of slag throughout the mass, has been the only agent at work to produce this alteration of texture. This experiment appears to me conclusive.

Those siderurgists who see in the grain of iron only the influence of carbon, will probably say to me that the prolonged sojourn of this iron in the furnace, in contact with the cinder, has caused a loss of carbon; and hence, the iron being more decarbonized, it is not surprising that its texture should have changed. They are led thus to object to my theory because steel almost always has a granular appearance; and, as between iron and steel, there is only the difference of a greater or less content of carbon, they attribute its granular condition to the presence of this metalloid.

Their objection falls, however, when we reply that steel drawn out into thin plates is, not unfrequently, fibrous. Puddled steel gives this fibrous product often; but it is capable of being tempered quite as well as that which is granular. The objection, moreover, becomes entirely untenable when we state that it is possible to bring back this same fibrous iron to the granular condition by a single operation, and that not capable of giving carbon to it; i. e., by exposing it to a welding heat, which expels the cinder and permits a perfect welding.

From these facts, I believe that I am entitled to affirm that the fibrous texture of iron is not inherent in the material itself.

The transformation of the granular into the fibrous texture, either by cooling or by a deficiency of temperature at the moment of welding, may now be considered as established in an incontestable manner.

To be continued.

PHOSPHOR-BRONZE.*

By C. J. A. Dick.

Phosphor-Bronze has for some years past attracted general attention in all the scientific, military and industrial circles of Europe and the United States. The invention is due to the owners of the Belgian Nickel Works of Val-Benoit, to whom the execution of very extensive tests with different compositions of bronze for Ordnance, was entrusted by the Russian Government. They succeeded in establishing as a scientific fact, the great superiority of phosphorized alloys of copper and tin, and in advancing the manufacture of these alloys on a large scale, to a state of perfection.

Many of the European military powers have conferred upon the inventors the highest honors and decorations attainable by civilians; the several phosphor-bronze works established on the continent of Europe have been eminently successful, and in England a powerful company has recently been organized for the purpose of fully working the new alloy in all its branches and applications.

In the United States the invention was patented a few years ago, and the writer, who controls the enterprise in this country, has since obtained patents for sundry improvements. Smelting works have for some time past been in operation in Pittsburgh, Pa., producing large quantities of phosphor-bronze and supplying the Pittsburgh mills and some of our leading railroad companies. The increasing demand for this new alloy is soon to be met by the establishment of additional works in Philadelphia or New York.

The chemical action of phosphorus on the metals composing the alloy is claimed to be two-fold; on the one hand it reduces any oxides

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[* The following notes on the new alloy, phosphor-bronze, were prepared by Mr. Dick for a gentleman of this city, who, deeming them of importance, has sent the paper to us for publication.—Ed.]

dissolved therein, and on the other it forms with the purified metals a most homogeneous and regular alloy, the hardness and the toughness of which are completely under control.

We give the records of some of the tests made by the highest European authorities, such as Mr. David Kirkaldy, Col. Uchatius, and the Testing House of the Prussian Royal Academy, all of which will be found of great interest.

No other metal or alloy combines in so high a degree as phosphor-bronze, the conditions of toughness, rigidity, hardness, and great elastic resistance. From the drop-tests hereafter stated, its comparative relation in this respect, to some of the best grades of wrought iron is made very apparent, and it seems almost incredible that a simple casting should not only equal, but by far overreach products upon which the most laborious working, hammering, rolling, and high mechanical skill have been expended.

Mr. David Kirkaldy's experiments with qualities of phosphor-bronze, sufficiently ductile to be drawn into fine wire, or rolled into sheets, determine its superior value as compared with brass, copper, coke-iron, charcoal-iron and steel, for all such manufactures.

The non-liability of phosphor-bronze to crystallize under heavy and often repeated strain or continued vibration, is demonstrated by the elaborate tests made and now making by the Prussian Government, the results of which, in this particular, place phosphor-bronze far above any competing material. Moreover if, jointly with this quality, the fact of the total absence of easily corroded metals, such as zinc, be taken into consideration, the advantages offered by the use of phosphor-bronze can scarcely be over-estimated. The effect of sea-water or of diluted sulphuric acid on phosphor-bronze is but slight, and much less than on copper.

A peculiarity of phosphor-bronze, the value of which will be appreciated by practical metallurgists, is, that in remelting the metal, not a particle of its component quantity of tin is "burnt out," that it makes castings of unrivaled soundness, and, that being as liquid as quicksilver, it fills even the most minute impression in the mould and can be cast in chills to great advantage. Its point of fusion is practically the same as that of ordinary gun metal.

Some of the experiments above alluded to, are stated in the following tables:

Table I.

Results of experiments to ascertain the Tensile Strength and resistance to Torsion of various Wires.

By Mr. David Kirkaldy, London.

Specimens of Wire tested.	Pulling Stress per square inch.		Ultimate extension in per ct.	Number of twists in 5 inches.*	
	hard.	annealed.	annealed.	hard.	annealed.
Copper	63,122 lbs.	37,002 lbs.	34·1	86·7	96
Brass	81,156 "	51,550 "	36·5	14·7	57
Charcoal Iron	65,834 "	46,160 "	28	48	87
Coke Iron	64,321 "	61,294 "	17	26	44
Steel	120,976 "	74,637 "	10·9	*	79
Phosphor-Bronze No. 1.	159,515 "	58,853 "	46·6	13·3	66
do. do. No. 2.	151,119 "	64,569 "	42·8	15·8	60
do. do. No. 3.	139,141 "	54,111 "	44·9	17·3	53
do. do. No. 4.	120,950 "	53,381 "	42·4	13	124

*Of the 8 pieces of Steel tested, 3 stood from 40 to 45 twists and
5 " " 1½ " 4 "

Table II.

Result of experiments to ascertain the Resistance to Extension, Set and Rupture under gradually increased pulling stress.

By the same.

Specimens.	Elastic stress per square inch.	Ultimate stress per square inch.	Ultimate permanent extension in per cent.
	lbs.	lbs.	per cent.
Phosphor-Bronze No. 1.	55,200	73,987	3·2
do. do. No. 2.	40,500	63,653	9·4
do. do. No. 3.	26,300	54,060	31.3

Table III.

By Col. Uchtaius, Director of the Imperial Ordinance Works, Vienna, Austria.

Specimens.	Absolute resistance in kilos per square centimeter.	Elastic resistance in kilos per square centimeter.	Stretch in per cent.
	kilos	kilos	per ct.
Phosphor-Bronze No. 0.	3600	600	20·66
do do No. 00.	5660	3·800	1·6
Krupp Cast Steel	5000	1·000	11·
Ordinary Gun Metal	2200	385	15·

TABLE IV.

A.—*Tests by repeated application of direct strain.*

By the TESTING-HOUSE OF THE ROYAL ACADEMY OF INDUSTRY, AT BERLIN PRUSSIA; these tests are being made by order of the Prussian Government.

PHOSPHOR BRONZE.			ORDINARY GUN METAL.		
NO.	Tensile strain per square in.	Number of efforts until rupture.	No.	Tensile strain per square in.	Number of efforts until rupture.
1	10 Tons.	408,350	1	10 Tons.	Broke before total strain was applied.
2	12½ “	147,850	2	10 “	4,200
3	7½ “	3·100,000	3	7½ “	6,300

B — *Tests by repeated bending in the same direction.*

PHOSPHOR-BRONZE.			ORDINARY GUN METAL.		
NO.	Tensile strain per square in.	Number of Bends until rupture.	NO.	Tensile strain per square in.	Number of Bends until rupture.
1	10 Tons,	862,980	1	10 Tons,	102,650
2	9 “	4 Million not yet broken.	2	9 “	150,000
3	7½ “	3 “	3	7½ “	837,760
4	6 “	2 “			

C. *Tests by repeated double twisting.*

A bar of hammered *Phosphor-Bronze,* under a strain of 12 Tons per square inch, has until now, *without breaking,* stood more than 2½ *million* twists, whilst according to Wohler's experiments, a bar of *Krupp Cast Steel* under 12 Tons strain, *broke* after 879,700 twists, and another bar of the same under 13 Tons strain, *broke* after 1,007,550 *twists.*

DROP-TESTS MADE AT THE PITTSBURGH WORKS.

Weight of drop 148 pounds; height of stroke 12 inches, except where otherwise stated; distance between supports, 4 inches; striking-face of drop, a blunted wedge-shape; test bars, 6 inches long, 2 inches wide, and ½ inch thick.

The letters inserted in the following table indicate the state of the surface of the test-bar, on the side upon which the blow has been given: *a,* sound; *b,* slight cracks at edge; *c,* cracks at edge increase in size; *d,* slight cracks in the middle of the test-bar; *e,* cracks in middle increase in number; *f,* cracks in middle increase in size; *g,* remains unaltered. —, straight. ⌒, test-bar reversed.

DROP TESTS.

The fractions of inches stated in the table represent the permanent set of the test bar after the blow.

Metals Tested:	*Number of Blows.*																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Phosphor-Bronze, XIV., B.	$\frac{3}{16}$ a	$\frac{1}{4}$ a	$\frac{3}{8}$ a	$\frac{7}{16}$ a	$\frac{1}{2}$ a	$\frac{5}{8}$ a	$\frac{11}{16}$ a	$\frac{3}{4}$ a	$\frac{25}{32}$ a	$\frac{13}{16}$ d	$\frac{7}{8}$ g	$\frac{15}{16}$ g	1 ÷ f	$\overset{\frown}{\frac{3}{4}}$ a	$\frac{11}{16}$ a	$\frac{9}{16}$ d	$\frac{1}{2}$ f	$\frac{3}{8}$ Broke. f		
Phosphor-Bronze, 6×17.	$\frac{3}{16}$ a	$\frac{3}{8}$ a	$\frac{1}{2}$ a	$\frac{5}{8}$ a	$\frac{23}{32}$ a	$\frac{13}{16}$ a	$\frac{15}{16}$ a	1″ a	$\overset{\frown}{\frac{7}{8}}$ a	$\frac{3}{4}$ a	$\frac{9}{16}$ a	$\frac{1}{2}$ a	$\frac{3}{8}$ a	$\frac{1}{4}$ a	— a	*3 foot blows,* 1″ b	$\frown$ a	Broke.		...
Rolled Charcoal Scrap Iron, best quality.	$\frac{1}{4}$ a	$\frac{1}{2}$ l	$\frac{11}{16}$ g	$\frac{29}{32}$ g	$1\frac{3}{32}$ g	$\overset{\frown}{\frac{7}{8}}$ a	$\frac{9}{16}$ a	$\frac{7}{16}$ a	$\frac{3}{16}$ a	— a	*8 foot blows.* $1\frac{5}{16}$ a	$\frown$ d	Broke		...	...	...	...	...	...
Best Charcoal Fire Box Plate Iron.	$\frac{5}{32}$ a	$\frac{9}{32}$ a	$\frac{7}{16}$ b	$\frac{9}{16}$ c	$\frac{11}{16}$ c	$\frac{13}{16}$ c	$\frac{29}{32}$ c	1″ c	$\overset{\frown}{\frac{13}{16}}$ a	$\frac{5}{8}$ a	$\frac{7}{16}$ d	$\frac{1}{4}$ Broke. f			...	...	...	...	...	...
The same, cut crosswise off plate.	$\frac{3}{16}$ b	$\frac{3}{8}$ c	$\frac{9}{16}$ c	$\frac{3}{4}$ Broke. c		...	.....	...	...	...	.....	.	.....	...	...	...	...	...	...	...
Charcoal Tank Plate Iron.	$\frac{1}{8}$ a	$\frac{9}{32}$ b	$\frac{7}{16}$ c	$\frac{9}{16}$ c	$\frac{3}{4}$ Broke. c		.....	...	...	...	.....	...	.....	...	...	...	...	...	...	...
Best Forged Charcoal Iron.	$\frac{3}{16}$ d	$\frac{3}{8}$ f	$\frac{9}{16}$ fe	$\frac{11}{16}$ f	$\frac{13}{16}$ f	$\frac{15}{16}$ f b	$1\frac{1}{16}$ fc	$\overset{\frown}{\frac{13}{16}}$ d	$\frac{11}{16}$ f	Broke.		...	.....	...	...	...	...	...	...	...

It is apparent from these drop tests that the rigidity of phosphor-bronze is greatly superior to that of iron, for it takes 13 blows to bend the bar XIV B to the depth of one inch, whilst the best quality of forged charcoal iron takes eight blows, and best charcoal scrap iron but six blows for the same bend.

The strength of the phosphor-bronze bar No. 6×17 is superior to that of best charcoal scrap iron, it having stood five more blows of 12 inches than the latter before being again completely straightened, the number of blows from a height of eight feet (3) given thereafter, being the same in both cases. The relative strength of phosphor-bronze as to that of other qualities of iron tested, needs no comment.

The application of phosphor-bronze to military purposes has undergone thorough investigation. Several European governments have experimented on the use of the alloy for making cannons; without any exception the results showed a much greater resisting power over that possessed by ordinary bronze. The following instances will be of general interest:

In Belgium the ordinary bronze gun burst at the second shot, with a charge of 1 k 250 gr. ($2\frac{3}{4}$lb) of powder and a cylindrical projectile weighing 8 k. 518 gr. ($18\frac{3}{4}$ lbs.) The phosphor-bronze gun supported this charge perfectly; the normal charge was 500 gr. (1 1-10 lbs) of powder and 3 k. ($6\frac{2}{3}$ lbs) of projectile.

In France, the ordinary bronze gun burst at the second shot, with a charge of 1 k. 500 gr. ($3\frac{1}{2}$ lbs.) of powder and 16 k. ($35\frac{1}{4}$ lbs) of projectile, while the phosphor-bronze gun was fired five times with this charge, and with a charge of 1 k. 750 gr. ($3\frac{7}{8}$ lbs.) of powder and a projectile of 20 k. (44 lbs.) it burst at the second shot, owing to the wedging of the projectile in the barrel. The normal charge was 550 gr. ($1\frac{3}{8}$ lbs.) of powder and a shell of 4 k. (8 4-5 lbs.)

In Prussia it was shown by firing with the regulation charges, and diminishing, at each 50 shots, the exterior diameter of the chamber, that the phosphor-bronze cannons changed their dimensions, only when the thickness of the metal was below that of the dimension of a cannon of the same calibre made of steel.

A large order has lately been given by the Prussian Navy Department to the phosphor-bronze works in Germany, for the casting of its turn-table machinery of its monitors.

Phosphor-bronze is being used in the manufacture of rifles and revolvers with good results, and by repeated re-loading of cartridge-shells made thereof, it has been proved to resist a much greater number of discharges than any other material.

The following are some of the applications of phosphor-bronze for industrial purposes:

Pinions and Tooth Wheels.—M. M. V. Gilliaux, at Charleroi; Blondiaux at Thy-le-Chateau; Thorneycroft at Wolverhampton; De Wendel at Hayange, among many others, have used pinions and tooth wheels made of phosphor-bronze in instances where the separate parts might run the risk of sudden and violent shocks, some of these pinions weighing nearly 1½ tons. They have proved that such pinions never break, while it is found in long practice, that the teeth last double the time of those made of ordinary bronze. The alloy has for similar reasons been much employed for horological purposes and fine spur-wheels.

Tuyeres.—An article appeared in the London "*Engineering*" some time since, speaking highly in praise of phosphor-bronze as a material for tuyeres. It proved that they last far longer than similar tuyeres of ordinary bronze, and that after a year's use they presented neither sign of fissure nor incrustation by scoria of the furnace. These tuyeres have been tried in England and France, and in Germany their use has become greatly extended.

Pump Cylinders.—The perfect soundness and great resistance of phosphor-bronze make it highly suitable for the construction of barrels of pumps and hydraulic presses. Mr. Merryweather of London, is using it in his steam-fire-engines, and Messrs. McKean & Co., have extensively employed it in the construction of their St. Gothard Tunnel Machinery.

Piston Packing.—The alloy has given excellent results for this purpose; its great elasticity and the small amount of friction of its surface, gives it much advantage over the ordinary steel packing. For bushings of Connecting-Rod Eyes of the Three Cylinder Engines of Brotherhood & Hardingham, London, phosphor-bronze is found to be the only metal capable of sustaining this heavy work under high pressure steam.

Gunpowder Mill Machinery.—Extract from official pamphlet on Gunpowder Storage, published by order of the British Home Secretary:

"There is a metal known as phosphor-bronze, which may be usefully employed in connection with powder magazines. It possesses a strength little inferior to that of iron, without any liability to give forth sparks. For the keys implements and fittings, it may be usefully employed."

Heavy Shafting and Propeller Screws.—The rigidity of phosphor-bronze as shown by the foregoing tests, in combination with its great strength, make it a very valuable material for these uses; it is much in demand likewise for ships-bolts and piston rods.

Wire Cables and Ropes.—Phosphor-bronze having the advantage of not becoming crystalline under the action of repeated shocks, it is eminently fitted for making wire-rope, for submarine cables, inland wires, etc., and is unacted on by corrosive liquids as found in mines, and by the atmosphere.

It was desirable to ascertain its resistance to the chemical action of dilute sulphuric acid. For this purpose two similar sheets of copper and of phosphor-bronze were immersed in acid water of 10° Beaume strength, and at the temperature of the surrounding atmosphere; after three months it was found that the copper had lost 4·15 per cent. and the phosphor-bronze only 2·3 per cent.

Sheathing.—The alloy is readily rolled, and stands the action of sea-water much better than copper. In a comparative experiment made at Blankenberghe, lasting over a period of six months, between the best English copper and phosphor-bronze, the following results were arrived at:

The loss in weight due to the oxidizing action of the sea-water averaged for the copper 3·058 per cent. while that of the phosphor-bronze was but 1·158 per cent.

Bearings.—This most important application of phosphor-bronze has received particular attention in the United States, and most excellent results have been obtained. Any one using machinery will readily understand why a material which wears from two to five times better than best gun-metal, which is very much less liable to heat than gun-metal, and which, when heated, does not cut the journal, has received such general approval, not only by the mills in which it has been in long service, but by some of our large Railroad Corporations who have adopted it exclusively for locomotive and car brasses.

We can but say in conclusion, that a metal possessing qualities especially fitting it for such varied applications, will not fail to make its mark in all our great industries, and its price being but little over that of gun-metal, it will not only replace that alloy, but prove a most powerful competitor to iron and steel, wherever toughness, rigidity, elastic resistance and non-liability to crystallization or corrosion, are the qualities sought for.

APPENDIX.

FRANKLIN INSTITUTE EXHIBITION,

1874.

Competitive Trials of Steam Engines and Boilers.

The examination of all Steam Boilers entered for competition, will cover all the qualities comprised in the best types, and includes a test of their evaporative efficiency, which shall be one of the elements in determining which is the best.

The chief object of these comparative trials is, to display and compare publicly, the merits of the several Engines and Boilers exhibited.

A secondary object, is to reward the makers of the best Boilers and Engines.

These trials will be made under the following rules.

STATIONARY STEAM BOILERS.

1. Good Anthracite Coal of one of the following brands, viz: Buck Mountain, Harleigh Lehigh, Honeybrook Lehigh or Locust Mountain, of uniform quality and size shall be used in the furnaces of all Boilers under trial, except in those constructed especially for other kinds of fuel. The unconsumed coal, ashes and clinkers of each trial shall be deducted.

2. The feed-water shall be accurately weighed, and its temperature taken in the tanks each time they are filled, my moving the thermometer through every part of it; and also by a thermometer placed in the feed water-pipe just before it enters the boiler.

3. The steam shall be maintained in each Boiler during trial, as nearly as possible at a uniform pressure of 80 pounds per square inch. Where practicable, the dynamic value of the steam will be determined by working it through one and the same Steam Engine.

4. Natural draft only shall be used to create and maintain combustion, and its temperature as it enters the ash-pit shall be taken by thermometer, and the temperature of escaping gases by pyrometer placed in the flue, immediately beyond the Boiler, and shall be accurately noted.

5. The evaporative efficiency of each Boiler under trial shall be measured by its economic capacity for generating dry steam under the usual conditions of combustion, and best uniform and continuous management of the fires.

6. The temperature and pressure, and all other conditions of each trial shall be observed and noted at regular intervals, and shall be the same in all the trials as nearly as possible, in order to avoid complex calculations in making comparisons. Any conversions that may be necessary in making comparisons between the results of tests of different Boilers, in consequence of any necessary deviations from the conditions above stated, shall be made by Rankine's formula and tables for such purposes, [see "STEAM ENGINES, by PROF. RANKINE." pages 254, 255, 256, and 564,] and which may also be found published on pages 403 and 404 of the Journal of the Franklin Institute for December, 1873.

7. All the instruments used shall, before and after each trial, be tested in the presence of the Judges, to determine their accuracy, and all the readings of the several instruments shall be correctly noted.

8. The feed water tanks and pipes shall be placed above ground, so that leaks, if any, may be seen. The pipes leading from the feed-pumps to boilers shall have no branch connections, and the pipe from the tank to pump shall be entirely disconnected while it is being filled, and the pipe for filling the tank shall be disconnected when the pump is in operation. *All* the appliances used shall be placed in full view so that they can be observed at all times.

9. Every Boiler shall be used several consecutive days preceding the trial, in order to thoroughly dry the "setting," and the fires shall be kept up all the night previous. On commencing the trial, [the furnaces being well heated,] the fires shall be drawn—the furnace and ash-pit thoroughly cleaned—a fresh fire kindled, and at the end of the trial the fire shall again be drawn and weighed with the ashes and clinkers.

10. The Judges shall require the different firemen to exercise, as near as may be, equal skill in the management of the fires. Particular care should be taken to observe, during the continuance of the trial, that the uniformity of performance is maintained, and proper account be taken of any variations in the quantity of water or fuel used. No trial shall be of less duration than ten hours.

11. Every person assisting in making the trials, shall be under the control of the Judges, who shall have power to suspend or discharge for cause, and in this, as in all other matters pertaining to the trials, their decision shall be final.

12. In testing Steam Boilers and Engines, the following Record shall be kept, and such other information as shall be deemed of value.

OBSERVATION		Pressure by Steam Gauge.	POUNDS,		TEMPERATURES.				Intensity of flue draft	HORSE POW'R		Height of Water.
Number	Time.	Lbs. per sq. inch.	Coal	Feed Water.	Feed Water.	Steam	Flue.	Boiler Room.	in Inches.	per Indicator	per Dynamom'tr	
	A	B.	C	D	E	F	G.	H	I	J		

STATIONARY STEAM ENGINES.

1 The cylinders must be drilled and tapped at each end for half-inch gas pipe, and a cock attached thereto for connecting an indicator.

2. The power of steam engines shall be taken by indicator and by dynamometer or friction brake attached directly to the engine shaft, and to facilitate this, the engine shaft should preferably project twelve inches beyond the outer bearing.

PORTABLE STEAM ENGINES.

1. The method of testing portable Engines shall, as far as practicable, be the same as those prescribed for stationary Engines and Boilers.

2. In comparing results in this class of machines, greater importance will be attached to the effect as shown by indicator and dynamometer. in comparison with the fuel consumption, than to the quantity of water evaporated by the fuel.

The Record, and all other particulars of each test together with description of Boiler or Engine. including first cost, shall be published in the report of the Judges.

Chimneys shall be furnished by the exhibitors ; subject, so far as safety from fire is concerned, to the Committee on Buildings. Each exhibitor shall furnish his own fireman, or pay for same if furnished by the Institute.

The Institute will furnish the fuel for all the boilers in operation, and shall have the use and control of so many as shall be necessary to furnish steam to apparatus and machinery in operation.

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EDITORIAL.

ITEMS AND NOVELTIES.

The Passivity of Iron.—To produce in a certain manner the somewhat capricious phenomena of passivity, says M. de Regnon, I use iron wires or rods of fencing-foil, the surface of which is protected, for a certain length, by a glass tube or a layer of mastic. The free extremity, with a length of two to three centimeters, is plunged entirely in the acid.

I. An electric current *entering* by the iron into nitric acid, renders the iron passive while the current lasts; and after rupture of the current the iron remains passive. A current *leaving* by the iron destroys the passivity, and this change of state may be reproduced indefinitely. Iron acting as the positive electrode in a mixture of sulphuric acid and water, liberates oxygen, is weakly attacked, and becomes passive for nitric acid. A reversal of the current's direction destroys the passivity.

II. One may *stop* the attack of iron by nitric acid, by touching or (better) rubbing it in the nitric acid with a body that is a good conductor and not attacked by the acid, such as platinum or conducting charcoal. This action of charcoal explains why steel and cast iron become passive of themselves. The experiment succeeds better the larger the surface of contact, and the larger the total surface of the body which is not attacked. Further, the more concentrated the acid, the more easily is the passivity obtained.

III. The contact of a metal attacked by acid destroys, it is known, the passivity. If, then, we put in contact a passive iron wire and an active wire, the final effect will be either the attack or the passivity of both wires. We may unite in a single experiment these two contrary results; immerse the extremity of a piece of foil (the whole surface of which is exposed) in nitric acid to a length of two or three centimeters. After a short attack, the part immersed becomes passive, and is covered with a dark deposit containing carbon. This done, if we suddenly immerse the foil to a fresh length of three or four centimeters the attack commences from above, is propagated to the lower part, and, when the passivity is anew produced, we find the whole of the immersed length charged with black deposit. In this first case the active portion destroys the passivity of the extremity. If, on the other hand, we immerse the foil slowly in the acid, it will remain passive without the part newly immersed undergoing the least attack, as is evident from its clear and bright look. Here the passive extremity communicates its state to the other portion.

IV. We may bathe the end of a wire in water, without destroying the passivity, provided care is taken not to immerse the wire in the water beyond the protective mastic. We may even scrape the wire, in the water, with another passive wire, or with the end of a clean tube of glass, without its state being changed, and this experiment quite destroys the explanation of passivity by formation of an insoluble deposit.

V. I have tried the action of other liquids after having each time bathed the passive iron in pure water, and I have verified the proposition (already known): Oxidating substances are without action on passive iron. Deoxidating substances destroy the passivity.

VI. We may perceive that the actions of contact are reducible to electric actions, by means of the following experiments:

1. Connect together a wire of iron and a wire of platinum terminating in a spiral. Plunge the free end of the iron in the acid, and when the attack has commenced, introduce the spiral of platinum into the same glass or into another glass containing acid, and put in communication with the first by a bridge of platinum. In an instant the iron becomes passive. The same experiment succeeds on connecting iron with conducting charcoal instead of platinum.

2. On the other hand, connect an iron and a copper wire. Plunge

in the acid the free end of the iron, and render it passive by rubbing with platinum or with passive steel. This done, introduce the end of the copper wire into the same glass, or into another glass as above, and immediately the iron is attacked.

3. Plunge into a glass filled with acid, or into two glasses connected by a bridge of platinum, the two extremities of two wires of iron connected exteriorly by a conductor. If we then rub in the liquid one wire only with platinum, both become passive; if we touch one wire with copper, both become active. These experiments are more delicate than the preceding, owing to the electric resistance of the liquid.

VII. The passivity may be destroyed in another manner, which shows the *role* of electricity. Connect the wire of a galvanometer, on one hand, with a spiral of platinum or copper, which has been plunged in a conducting liquid that does not destroy the passivity, *e.g.*, a solution of nitrate of potash, and, on the other hand, with a wire of iron protected by mastic as explained. Then close the circuit by introducing the iron into the nitrate; the needle indicates an immediate and permanent current going from the galvanometer to the iron. We obtain the same result (which is easy to foresee), if, after rendering the iron passive, and washing it well with water, we immerse it an instant in a liquid which destroys the passivity: *e.g.*, in a solution of marine salt. But if we close the circuit after having washed the passive iron in water, or in a liquid *without* action on the passivity, we perceive a slight movement of recoil in the needle, indicating a first current of very short duration, going from the iron to the platinum by the galvanometer; then the needle is forced in the contrary direction, and indicates a permanent current from the platinum to the iron. But one finds that, immediately this action is produced, the iron has become active again.

VIII. All these experiments seem to me to legitimize the following conclusions:—1. Most of the causes which produce passivity in iron may be reduced to a voltaic force carrying the oxygen to the iron and polarising it on the surface of this metal. 2. Most of the causes which destroy the passivity of iron may be reduced, either to a voltaic force of the contrary direction, or to a current due to polarisation of the oxygen, and by which it is exhausted; or, lastly, to an absorption of the polarised gas by a body that has avidity for oxygen. I hope shortly to show that these phenomena of passivity are more general than is supposed.

IX. We can now explain two experimental precautions that were insisted on:—1. It is necessary to protect, with an impermeable layer, the portion of wire which is not plunged in the acid, otherwise the acid vapors bring this portion into a state which is opposed to the passivity of the immersed part. 2. When we bathe the passive extremity in water, the metal should not be immersed above the mastic, otherwise the passivity is immediately destroyed, for a circuit is closed by which the polarization is exhausted.

Most of the above experiments were made with nitric acid, marking 35 deg. B.—*Iron.*

Carbonic Acid Gas Engines.—The following account of the new Carboleum engine of Dr. Beins, which has recently created some excitement as a new motor, we take from the editorial columns of the *Engineer*. We value it especially because of the criticisms with which it is accompanied, which we regard as eminently just:

Faraday was, we believe, the first to liquefy a gas. He used small glass tubes, and an account of his experiments may be found in most treatises on chemistry. The subject was earnestly taken up by Thilorier, who devoted his attention principally to carbonic acid, which he succeeded in solidifying in considerable quantities. The apparatus he used was imperfect and caused some serious accidents. Natterer of Vienna produced a better apparatus, and this was improved upon by Bianchi, who produced a really workable gas-liquefying machine, by the aid of which carbonic acid in the liquid state can be produced by the pound. To make it, two things are necessary—a pressure of about 40 atmospheres, or 600 lbs. on the square inch, and a ready means of abstracting the heat developed by the work of compression. This last is usually supplied by a freezing mixture. The use of solid or liquid carbonic acid as a motor has often been proposed. But those who have mastered the laws of the conservation of energy will understand in a moment that carbonic acid or any other gas which admits of liquefaction, can not originate power. It can become a storehouse of power and nothing more. In a word, a pound of liquid carbonic acid will, in the course of its reconversion into gas, give out just the power expended in compressing it and no more. But a large proportion of that power was converted into heat, and this heat must be restored to the liquid before it can become gas. But the heat expended in liquefying carbonic acid is just the same, according to ordinarily received laws, as would be expended in compressing air to the same extent. That is to say, it will be raised in temperature one degree Fahrenheit if it is reduced in volume by 1-490th. If we compress carbonic acid gas to 32 atmospheres, or 480 lbs. on the square inch, the temperature will be raised to about 2450 deg., while the temperature due to 64 atmospheres would be 2940 deg. The specific heat of carbonic acid is ·217. A cubic foot of the gas at 32 deg. weighs 0·12259 lb. One pound under these conditions occupies 8·157 cubic feet. In rising to the temperature of 212 deg. it will expand ·365, and to raise one pound of carbonic acid one degree in temperature, 167 foot-pounds of work must be done. This last is really the important factor when we come to deal with carbonic acid as a motive power, and for the moment all else may be neglected. We have seen that by compressing carbonic acid gas into 1-32 of its bulk at atmospheric pressure the temperature will be raised, in round numbers, to 2450 deg.; but each degree by which we raise 1 lb. of the gas represents 167 foot-pounds; consequently the whole work that will be done in compressing 1 lb. of carbonic acid gas 32 times will be 167 × 2450 = 409,150 foot-pounds, which, if exerted in one minute, would represent nearly 12½ horse-power. Put in another way, the consumption of compressed carbonic acid gas would be about 5 lb. per horse power per hour, provided we could realize the whole of the force stored up in it. But it must be borne in mind that, during the work of compression, the whole of the heat squeezed out of the gas, if we may use the term, must be wasted; and before the gas can resume its original volume—do work in fact—this heat must be restored, and this being the case, it would be just as practicable to use air as carbonic acid gas. Neither possesses any advantage over the other worth consideration; unless indeed it can be shown that some method exists by which we can obtain carbonic acid gas under high pressure by the aid of fuel which would otherwise be wasted.

Bearing these facts in mind, we shall be in a position to understand a proposition just put before the world by Dr. H. Beins of Groningen. This proposition has reached us in the form of a circular, but indifferently translated into English from the Dutch. Dr. Beins' idea is, so far as we comprehend it, to heat bicarbonate of soda or potash to a high temperature under pressure, and thus to obtain carbonic acid gas, of high tension, or even in its liquid state. The definite statement is that "at a temperature of 300 deg. to 400 deg. C. liquid carbonic acid can be distilled out of these salts with a tension of from 50 to 60 atmospheres." We are not aware whether such a process has ever been tried before by chemists, and we shall not dispute Dr. Beins claim to be the first discoverer of the process. He proposes to utilize it in the production of motive power, and we shall now allow him to explain himself.

"One litre of *Carboleum*—liquid carbonic acid—of 50 deg. C. and a tension of 50 atmospheres weighs approximately 0·8 kilogram, and can produce 400 liters of carbonic acid gas of the ordinary atmospherical tension. Suppose now these 400 liters compressed to 50 atm. The work required for that compression is represented in every case (however much may be the anomaly with regard to Boyle's law) by a mathematical figure of the same area as the hyperbolical plane, that represents the power of compressing an equal volume of air to 50 atm. and this amounts to about 17,000 kilogrammeters. Per horse-power and per hour (270,000 kgrmmtr.) about 16 liters carboleum of 50 atm. and 15 deg. C. is thus required. Here and in the following I take for greater simplicity even numbers. Only when a carboleum engine works with great intermissions can the heat of vaporation required be taken from the sides of the reservoir without artificial heating. In the majority of cases, however, the carboleum must be evaporated by the artificial heating of small quantities at a time. The heat required per horse-power hourly (270,000 kgmmtr.) amounts at least to 640 calories (0·1 kilogr. of coal.) But now the objection may be made the quantity of carboleum required for an engine of greater dimensions and continuously working is too considerable, and therefore the reservoirs must be made too heavy. And for this reason carboleum would not be applicable otherwise than for small engines working with intermissions. The fact is that greater carboleum engines must work with regeneration. They must have a store of sodium bicarbonate and of carboleum, so that the decomposed bicarbonate is regenerated again by the carbonic acid that has worked in the engine. Such an engine transforms very advantageously the heat (furnished by the fire for decomposing the continually regenerated bicarbonate) in mechanical work. Supposing the gas working with a temperature of 100 C. the 16 liters of carboleum required hourly per horse-power are reduced to 10 liters. Such an engine requires about 0·3 kgrm. of coal per horse-power hourly, whilst the best steam engine requires 1.2 to 0·9 kgr."

The preceding calculations look very well on paper, but it is obvious that Dr. Beins believes that he can get something in the way of power for nothing in the way of coal. We have shown that the only result to be had from the use of liquid carbonic acid is a result purely equivalent to the power expended in compressing it. The work of regeneration, as the inventor calls it, depends on the application of heat; and the work done will be just the same whether the gas is compressed in the process of manufacture from bicarbonate of soda or potash, or by hand, or by a steam engine. The carbonic acid is as powerless in the whole cycle as the water in a boiler or the piston in an engine. It can originate nothing, and it does not require much experience to become aware of the fact that carbonic acid is an exceedingly inconvenient medium to deal with in the development of power from fuel; and to fuel Dr. Beins must ultimately resort. There may, perhaps, be situations in which carbonic acid gas could be made useful for driving small engines; but they must be few and far between. It is not impossible, however, that the proposed system of obtaining carbonic acid gas under high pressure may prove of considerable commercial importance, as, for example, in the aerated water trade.

The Stevens Institute Mechanical Laboratory.—The following is the text of the letter from the Trustees of the Stevens Institute of Technology at Hoboken to Professor R. H. Thurston, establishing the Mechanical Laboratory which he had suggested. The idea is a most excellent one and is as important as it is novel:

SIR:—The Trustees, after a more thorough consideration of your letter of January 30th, referring to the necessity of a laboratory devoted to technical research, and especially designed to meet the necessities of the industrial interests of the country, have decided to assume the initiative, and to endeavor to provide the nucleus of such an institution as that proposed in your letter just referred to. You are, therefore, authorized and requested to organize a Mechanical Laboratory, as an adjunct to your department, and to assume the direction of its affairs.

You will take charge of such contributions as may be made by those interested in the creation of such an establishment, whether of apparatus, of machinery, or of capital, and account for them to the Trustees. In accepting such contributions, you will submit to the Trustees the proposed conditions of acceptance before completing any agreement with the contributors. You will, in the expenditure of funds, in the erection of buildings, the purchase and establishment of apparatus and machines, and in the employment of subordinates, use every precaution to secure the greatest economy, and a full equivalent for funds so used. You will establish all necessary regulations for the successful operation of the new department, and will provide such a schedule of charges for work done for private parties as shall cover actual expenses and give a margin of profit, amounting to not less than twenty per cent. of such expenses, which profit shall be charged to a capital account for the purpose of securing a gradual increase of the stock of apparatus, and the accumulation of a fund which may ultimately be used in the erection of buildings, and in securing enlarged facilities for special researches. In making regulations for the guidance of those having occasion to avail themselves of the facilities which it is proposed to provide for the examination of materials and for research, you are desired to make provision, where possible, for a fair return upon their investments to those who may aid in the establishment of the Laboratory.

You will make a report to the Trustees in January of each year, in which you will state the amount, and the character of work done during the previous year, the condition of the department; its growth, and its wants. You will be expected to render an account of receipts and expenditures semi-annually, January 1st and July 1st; and in the statement, which shall accompany the annual report, you will give an account of stock, and a statement in full of the value of all property held on Laboratory account.

The Trustees of the Stevens Institute will transfer to the Director of the Mechanical Laboratory the following property, to be held and used for the benefit of said Laboratory:

1 Steam Engine of 4 horse-power; 1 Engine Lathe of 15 inch swing; 1 Speed Lathe; 1 Power Planing Machine, 5 feet bed; 1 Small Hand Planing Machine; 1 Universal Milling Machine; 1 Upright Drill; 1 Emery Grinder and Wheels; 1 Set of Tapsand-Dies; 1 Set Reamers; 1 Set Whitworth's Gauges; 1 Lot Miscellaneous Tools, as per inventory to be submitted; 1 Testing Machine, with autographic registry, to break iron and steel $\frac{5}{8}$ inch diameter; 1 Emerson Dynamometer; 1 Salleron Dynamometer; 1 Woltmann Mill, for determining velocity of streams; 1 Baumgarten Mill, for determining velocity of streams; 1 Wheel, with Dial for determining velocity of water; 1 Pilot Tube, with Dial for determining velocity of water; 1 Anemometer; 2 Richards Steam Engine Indicators; 1 MacNaught Steam Engine Indicator; 2 Spring Balances, British Measure; 1 Spring Balance, French Measure; 1 Blacksmith Forge.

To the above list there will be appended some other apparatus as yet unselected, the whole having an estimated value of $5000.

The boilers of the Institute will be allowed to furnish steam to drive the engines and tools.

The Trustees will assume charge of permanent funds, and will endeavor to invest them properly. They will decide when it may be advisable to expend all or any portion thereof for the purpose of enlarging the field of usefulness of the institution for the benefit of which they may have accumulated.

You are authorized to make use of such available space within the building of the Institute as shall be necessary for the accommodation of the proposed Institute, and to call upon the employees for such assistance as may be needed, whenever such aid may be rendered without interfering with their regular work, or their duties to the officers of the Institute. It is presumed that such assistance will meet all requirements for several months at least.

Whenever it shall occur that a total subscription of sufficient amount to erect buildings shall have been received, the Trustees will further appropriate to the use of the proposed Mechanical Laboratory a strip of land adjacent to the Stevens Institute of Technology, not exceeding two hundred feet in length and fifty feet in breadth, valued, at present prices, at not above twenty thousand dollars, on which such buildings may be erected.

The total appropriation thus made is to be credited to the Institute as a shareholder, for its amount, $25,000. The Trustees will also hold themselves in readiness to share the management of the Laboratory with a Board of Trustees, of which the President of the Stevens Institute shall be *ex-officio* President, and on which Board contributors shall have representation in proportion to the aid given ; this transfer to take place whenever the majority of stock representing subscriptions shall vote it advisable.

A New Motor.—According to the laws of the mechanical theory of heat, any difference of temperature may be employed for the production of mechanical work. If a cold body then, be situated in air that is hotter, the passage of heat to it should be capable of giving mechanical work. The solution of this problem, M. Enrico Bernardi, an Italian physicist, has recently sought to realize in the following way : (*Il Nuovo Cimenti*, 2, xi. 27.)

Two similar glass balls are connected together by a thin glass tube, the ends of the tube passing into the balls, being bent at a right angle. One ball contains a small tube, by which ether can be poured into the apparatus; the ether is brought to boiling, and when all the air has been expelled, this small tube is closed by fusing. The quantity of ether enclosed in the system should be such as to fill about three fourths of one ball. At the middle of the connecting tube is fixed a piece through which passes a metallic axis, round which the system can turn. When the ether is equally divided between the two balls, the apparatus is in unstable equilibrium. The bearings for the axes are supported on the cover of a rectangular case, and in this cover is a slit through which the turning system passes. The case is filled with water into which the balls dip alternately on their being turned round the axis. Each ball is covered with a very fine veil. It is easy to see that this apparatus will take a sea-saw motion.

"In this apparatus," says M. Bernardi, "there is a continuous flow of heat from the surrounding parts to the case, as the water in this is kept at a lower temperature through the balls, which, cooled by evaporation, periodically sink into it. If we were to draw a comparison between my apparatus and a steam-engine, we should assign to the surroundings the *role* of the fire, to the case that of the furnace, to the under ball that of the steam boiler, to the upper that of the condenser. In this way it would be readily understood, that the work developed in the apparatus is a transformation of a portion of the heat which continuously passes from the surroundings to the case."

It would be rather troublesome to utilize this thermo-motor see-saw mechanically, and M. Bernardi has, therefore, preferred to alter the apparatus in the following way: The two balls of the above described system are connected by a tube, the ends of which are bent round (at right angles) to opposite sides. Three such systems are formed into a sort of wheel, the middle points of the six balls and the tubes being in one plane. This wheel is supported at its axis, on the cover of a rectangular case in such a way that, in its rotation, it is always half within the case and half in the air. The balls are covered, as before, and so much water is poured into the case, that, in turning the wheel, one ball is always immersed. By giving the wheel a turn it can be set in continuous rotation, and, with a suitable arrangement of pulleys, it can be made to raise a weight, or do other work.

Such a thermo-motor wheel has, for two months, been working a clock, in M. Bernardi's laboratory. The balls have a diameter of two centimeters (·8 inch;) the distance of the middle points of two opposite balls is eight centimeters (3· 2 inches,) and the quantity of ether in each system fills three-fourths of a ball. The clock maintained in motion by this wheel consumes, in 24 hours, 0.035 kilogrammeter. The water level is kept constant by a special arrangement.

In both see-saw and wheel, the dissolved salts of the constantly evaporating water must gradually be concentrated. The less soluble appear crystallized on the surface of the balls and of the case; the soluble salts delay the evaporation, and so lessen the quantity of heat withdrawn from the balls, and therewith the work furnished. The evil is remedied if distilled water, rain-water, or snow-water, is used; otherwise the apparatus must occasionally be cleansed by means of dilute muriatic acid or by nitric acid. Using the ordinary drinking water of Vicenza, M. Bernardi has had his see-saw working for three months withont its becoming necessary to renew the water or to clean the balls.

The author has tried to calculate the quantity of heat which is removed by this apparatus from the surroundings. To this end, he so arranged a see-saw, that each time when the balls passed through the opening in the cover, this opening closed, and the water was thus always in a closed space. This space was further protected against variation of temperature by means of a water-jacket. As the water by this arrangement, was guarded against all loss of heat, the work of motion furnished the data from which could be estimated the heat consumed. In a window not exposed to the sun, observations were made from the middle of February, to the middle of March, and there was an average of sixty see-saw motions in twenty-four hours. Calculating, from the weight of the ether, and the change in the center of gravity at each turn, the amount of work done in twenty-four hours, this was found to be equal to 0·018 kilogrammeter, or about half the work consumed in the same time by the clock.

As to the "moments" which affect the amount of work furnished by these apparatuses, they depend, first of all, on the quantity of heat which in a unit of time is removed through evaporation of the water of the upper ball, and so on the temperature and moisture of the air and of the moistened surface of the balls. Further, the thickness of the balls is of influence and under conditions otherwise, the number of units of heat which the contents of the ball lose in a unit of time is less, the thicker the glass. The rapidity with which the see-saw movements follow one another, is, lastly, influenced by the somewhat rapid variation of the air; the movements become more frequent if the temperature of the surroundings falls, and more seldom if it rises; for the water in the case cannot follow so quickly the variations of temperature.—*English Mechanic.*

A New Joint for Boxes.—A method for making joints to unite the sides of boxes and other matters, has been recently patented in England, by Mr. W. M. Beaufort. The two pieces of wood to be fastened together are first mitred in the usual manner, and a hole is then drilled vertically in each piece, from the bottom upwards at a short distance from the mitred edge. A channel or groove is then cut, by a saw or otherwise, from the mitred edge to the drilled hole. This channel is of a less width than the diameter of the hole, and may be cut either parallel to the sides of the piece of wood, or at right angles to the mitre, so that when the two pieces of wood are put together, a continuous channel shall be formed between the two holes. The two pieces are then held tightly together and a key is formed by running metal such as lead, or fusible metal into the channel; by this means the key is cast in the place which it is to occupy. The key may also be made separately, of solid metal, and driven home into the channel.

Improved Tuyere for Forges.—We find in the English journals, the following notice of a paper read by Mr. W. Smyth, before the British Association, which described a very simple but important improvement in smith's forges, by which the forge is much more fully under the control of the workman, and by which the life of the tuyere is greatly prolonged, the work of heating the metal more uniformly and uninterruptedly carried on and a great economy of fuel effected. A cast-iron trunk or box is placed horizontally from the back and front of the forge. The front end is closed by means of a slide or door. The back end has a hollow tower which rises above to a suitable height, and upon which is fitted a cast-iron tuyere block, with by preference, two long slot-holes for the blast. Within the trunk is a long lever working in an axle or spindle, which at its longer end has two punches which rise vertically, and are from time to time projected through the slots to displace the slag and keep the tuyere openings clear. This the workman does, by moving a lever upon the outer end of the spindle or fulcrum of the levers. The iron trunk or box becomes heated by the surrounding fuel, and utilizes the heat, which would otherwise be wasted; thus effecting a considerable economy of fuel by heating the air of the blast.

Editorial Correspondence.

[The following letter from Col. G. Howard Ellers, C. E., upon the use of Nitro-glycerin in blasting, was written at the request of a gentleman of this city, for a friend of his at the West, who desired to use this explosive practically. Deeming the facts it contains of general interest to our readers, we have obtained a copy of the letter for publication.—Ed.]

On the Use of Nitro-glycerin in Rock and Earth Excavations.

My Dear Sir: I have the honor to acknowledge the receipt of your communication of the 21st inst., and in response thereto, beg leave to say, that in such material as you describe, cemented or indurated earth, hard pan, etc., etc., the use of nitro-glycerin will scarcely be found as economical as powder. In the older rocks, granite, gneiss, limestone, quartz, etc., nitro-glycerin will do the work at fully half the cost as compared with the best blasting powder. There are many different qualities of nitro-glycerin, varying fully fifty per cent. in power and purity, and, while the pure article is *perfectly safe*, and does not readily change in store or magazine, the spontaneous explosion of an impure article is merely a question of time and temperature. There are many circumstances controlling the use of this most valuable explosive agent, a proper knowledge of which will often save both time and money;—for instance—a diffusion of *ten per cent. of water* will *diminish* its blasting power thirty per cent. while an increased power of fully thirty per cent. is obtained by charging directly in the drill hole *over what is evolved,* when the metallic shell of the cartridge and a stratum of air and water are interposed between the gases of explosion and the rock acted upon. I am unable to say how much *loose earth* a given charge will move or throw down, never having used it in anything but rock and large erratic boulders, and I know of no one from whom such information can be obtained. As I have already said, the maximum useful effect of nitro-glycerin, as a blasting agent, is reached in the older and harder rocks; in loose material it is not so effective. The following are substantially Mr. Mowbray's instructions for use and handling, and he probably knows more about the subject than any man in America :

1. Handle with the greatest care, avoiding every possible jar or concussion, and be very careful, if any is spilled outside the can, *to avoid striking it with or against any hard substance.*

2. When in a solid state, thaw out by placing the cans in a vessel of *warm water, never warmer than the wrist can bear,* first pouring some of the warm water *from the vessel into the can,* and *always removing*

the can or cans before adding more *warm water* to that in the vessel in which the cans are placed.

3. When filling cartridges hold them carefully over a tray, about 2′ × 3′, the bottom of which must be thoroughly *covered* with "Plaster of Paris," which latter must be replaced as rapidly as lightly saturated with the nitro-glycerin. (Memo., plaster of Paris saturated with Nitro-glycerin *does not readily* explode.)

4. If necessary to store nitro-glycerin in a liquid state for any length of time, *insert the cork loosely*, and pour a pint of *cold water* in each can, which water must be frequently and carefully poured oft and *replaced with fresh cold water* in *warm weather*, always taking care to retain the bladder under the cork. If ice can be procured, however, it is both safer and more desirable to congeal the nitro-glycerin and keep it in the solid state.

5. Use gutta percha funnels for filling water holes—never tamp the drill holes, it is totally unnecessary and is pretty sure to kill the individual who does it.

6. Never use hot irons to warm the water, or for soldering the cans, both are sure to cause explosions.

7. Never sledge or drill in a hole or seam where nitro-glycerin has been spilled, without first firing an exploder to clean the place out.

8. Never pour nitro-glycerin into a hole, unless perfectly sure that the hole is sound and will hold water; if otherwise, always use a cartridge.

9. To obtain the best results, use drill holes always 6 feet in depth, or over, fire with powerful exploders and well insulated wire, by electric battery and with simultaneous explosion.

10. After a blast, look carefully for any unexploded cartridges that may be laying around loose.

11. Allow none but the most careful, competent, and sober persons to handle or have charge of nitro-glycerin, and enforce a rigid obedience to orders and compel the adoption of every precaution to prevent accidents or explosions.

12. Never use empty cans for other purposes, transport them to a safe place, and then destroy them by fire, or with a fuse and exploder.

13. Carefully examine the cans from time to time, and notice if any pin holes have been eaten through at the level of the nitro-glycerin therein. Should the presence of such holes be detected, procure new cans or stone jars, and place the contents of the unsound cans therein, never trusting your hold on the upper portion of the unsound cans, lest it break loose and trouble ensue.

14. When congealed, nitro-glycerin is absolutely safe; if possible, therefore, it should always be stored surrounded with ice, since explosion is impossible when in a solid state.

The present price is about $1.65 per pound delivered—the electric exploders are about 30c. for 10 feet wires, and 25c. for 8 feet wires. Some changes in these figures may be made about the first of next month. If you have any important work on hand requiring the use of nitro-glycerin, or of a difficult or dangerous character, I shall be most happy to undertake it at any time.

Trusting the foregoing may meet your requirements, I am, etc., very cordially yours,

(*Signed,*) G. HOWARD ELLERS,
Chief Engineer.

Troy & West Troy Bridge Co.,
Chief Engineer's Office, Troy, N. Y., May 25, 1874.

Prompt Passenger and Freight Transportation in New York.—The American Society of Civil Engineers has taken in hand the matter of a cheap and ready method for transporting passengers and freight in New York city. Its Committee desires communications upon the subject, as will be seen by the annexed circular, which has been sent to us for publication:

"At the regular meeting held September 3d, 1874, it was—

"RESOLVED, that a Committee of five members of this Society be appointed by the President, to investigate the necessary conditions of success, and to recommend plans for—First: The best means of rapid transit for passengers, and Second: The best and cheapest methods of delivering, storing and distributing goods and freight, in and about the city of New York; with instructions to examine plans, and to receive suggestions such as parties interested in the matter may choose to offer, and to report on or before the first day of December, 1874.

Messrs. O. Chanute, M. N. Forney, Isaac C. Buckhout, Charles K. Graham and Francis Collingwood were appointed such Committee.

You will confer a favor upon the Committee and the Society by furnishing whatever contribution or suggestions you may deem of value on the above subjects, or by calling attention to the sources of such information. Due credit will be given for all aid rendered to the Committee.

In referring to plans proposed to accomplish these objects, it is particularly desired to ascertain accurately—First: The route and location proposed, and the reasons therefor. Second: The character of structure proposed in various parts of the city. Third: A close estimate of the cost in detail.

It is greatly preferred that all communications shall be in writing. Please address,

G. LEVERICH, Secretary American Society of Civil Engineers,
63 William street, New York."

Franklin Institute.

HALL OF THE INSTITUTE, June 22d, 1874.

The meeting was called to order at the usual hour and Mr. Charles S. Close was on motion called to the chair. He announced that the purpose of the meeting was to exhibit and discuss the operation of Charles Henry Hall's Patent Pulsometer, and Prunty's Patent Automatic Relief valve and cut-off for fire-hose.

The meeting was conversational in its character. Messrs. G. W. Storer, S. L. Wiegand, Charles Bullock, Thomas J. Lovegrove and Professor R. E. Rogers participated in the discussion on the Pulsometer and elicited the following facts:

That the Pulsometer is economical for raising water for lifts not exceeding 26 feet; but in forcing water by pressure it derived no benefit from the expansion of the steam. The temperature of the water raised was increased about three degrees Fahrenheit.

Mr. Robert Grimshaw exhibited Prunty's Relief valve and cut-off applying them to tubes connected with the pulsometer which was forcing water under a pressure of steam of 80 pounds per square inch. In every instance the closing of the cut-off at the jet muzzle instantly opened the relief valve without any appreciable concussion, although more than 50 feet of fluid column was arrested between the jet tube and relief valve.

Mr. S. L. Wiegand announced that full descriptions of both inventions would appear in reports from the Committee of Science and the Arts, and that stereopticon illustrations of them were incourse of preparation.

On motion the meeting was adjourned.

(Signed) W. H. WAHL, *Secretary.*

Erratum.—In the August number of this Journal, in the table of drop tests for phosphor-bronze on page 143, in the third line near the end, the words "3 foot blows" should read "8 foot blows."

Civil and Mechanical Engineering.

THE STEVENS IRON-CLAD BATTERY.

[The famous "Stevens' Battery,"—the earliest of all iron-clads, so far as its earlier design and the actual commencement of its construction antedate all other structures of its class, and the most modern in plan and the fastest and most formidable of existing war vessels as now reconstructed by General McClellan,—is to be sold without reserve, and to the highest bidder on the second day of November.

The advertisement of the Consulting Engineer to the Commission appointed to effect the sale for the State of New Jersey and for the estate of Edwin A. Stevens, by whom the craft was bequeathed to the State, has made known the principal dimensions of the great steamer to the readers of all engineering, mechanical and naval periodicals, both in this country and in Europe.

The historical interests attaching to this powerful war-steamer, as well as the exceptionally formidable character of the iron-clad itself have induced us to procure for our readers the following abstract of the report of Professor Thurston, the Consulting Engineer. This report has been published in full and in beautiful shape, for the Commission, by Van Nostrand.

The Commission consists of Governor Joel Parker, Vice Chancellor Amzi Dodd, the Hon. W. W. Shippen, and the Rev. S. B. Dod. —Ed.]

DESCRIPTION OF HULL AND MACHINERY.

HULL—GENERAL DIMENSIONS.

Length over all	401 feet.
" between perpendiculars	390 "
Breadth	45 "
" over armor	54 "
Depth to main deck	24½"
Draught, maximum, fore and aft	22 "
Displacement at 22 feet draught	6006·02 tons
Area of immersed midship section	890·26 square feet
Ratio of immersed midship section to circumscribing parallelogram	0·867
Ratio of displacement to circumscribing parallelopiped	0·544

The general appearance of the vessel, if completed as here proposed, will be that of a "Monitor" iron-clad, such as is illustrated in the accompanying engraving.

The form of the hull is shown in Plate I, Figs. 1, 2 and 4, on which are exhibited the lines as obtained by actual measurement of the completed hull. Figure 3 represents a cross section through the engine compartment.

The proportion of length to breadth—8·666 to 1—is that now usually observed in sea-going high-powered steamers, and is somewhat less than in those which represent the extreme limit yet attained. The lines are fair and fine, giving a sharp bow and the fine run which is essential to the efficient working of screw propellers. The proportions of the midship section, which has a breadth equal, very nearly, to double the intended draught, are such as are best calculated to make the vessel easy in a sea-way.

On Plate I, Figure 5, is shown the Curve of Displacement, as estimated from measurements taken by the Engineer in charge during construction, and as checked by the Consulting Engineer. The displacement per foot of draught at the intended load line is 424·19 tons, or 35·35 tons per inch. Removing the armor shelf, for the purpose of converting the ship to other use, the displacement at 22 feet draught would become 5,658 tons, and the additional displacement per foot of draught, would become 335 tons, or 27·9 tons per inch. In this case, it would become necessary to build up the ship one deck, and it might be advisable to build up two decks. If considered proper, an additional displacement could be thus secured, giving a total of 6,329 tons at 24 feet draught, which draught can be carried over the bar at the entrance to the harbor of New York, and into every important seaport of Europe.

The balanced rudder, shown in Figure 2 of Plate I, is one of the important and valuable features introduced into the design of this vessel by its inventor, Mr. R. L. Stevens.

The hull of the ship is double, the inner and outer skins being separated, as shown in Figure 3, by a space varying from 22½ inches at the bottom to 6½ inches at the top of the inner portion. Seven transverse bulkheads are built, dividing the ship into distinct watertight compartments. Two additional bulkheads are carried across the ship below the berth deck. Coal bunker bulkheads, forward and aft, and the several smaller bulkheads in the extreme ends of the vessel, still further strengthen the structure, and assist in securing

Stevens Iron-clad Battery. Plate I.

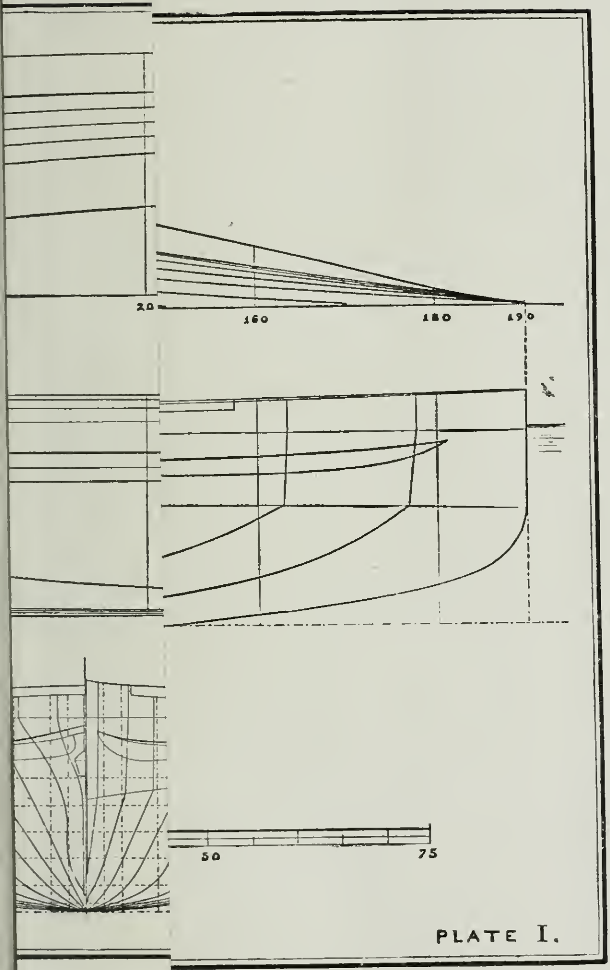


PLATE I.

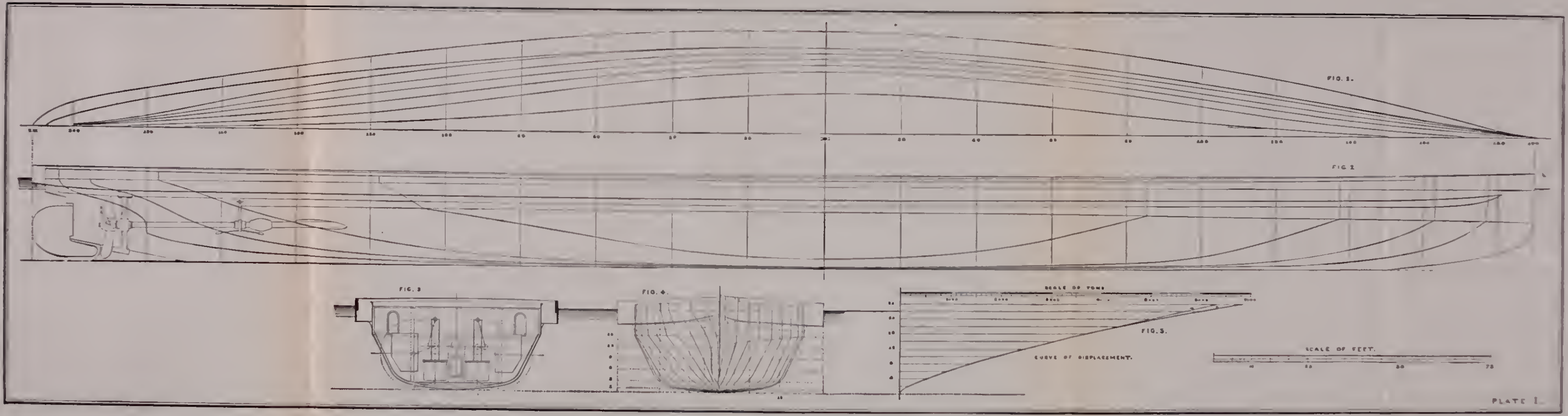
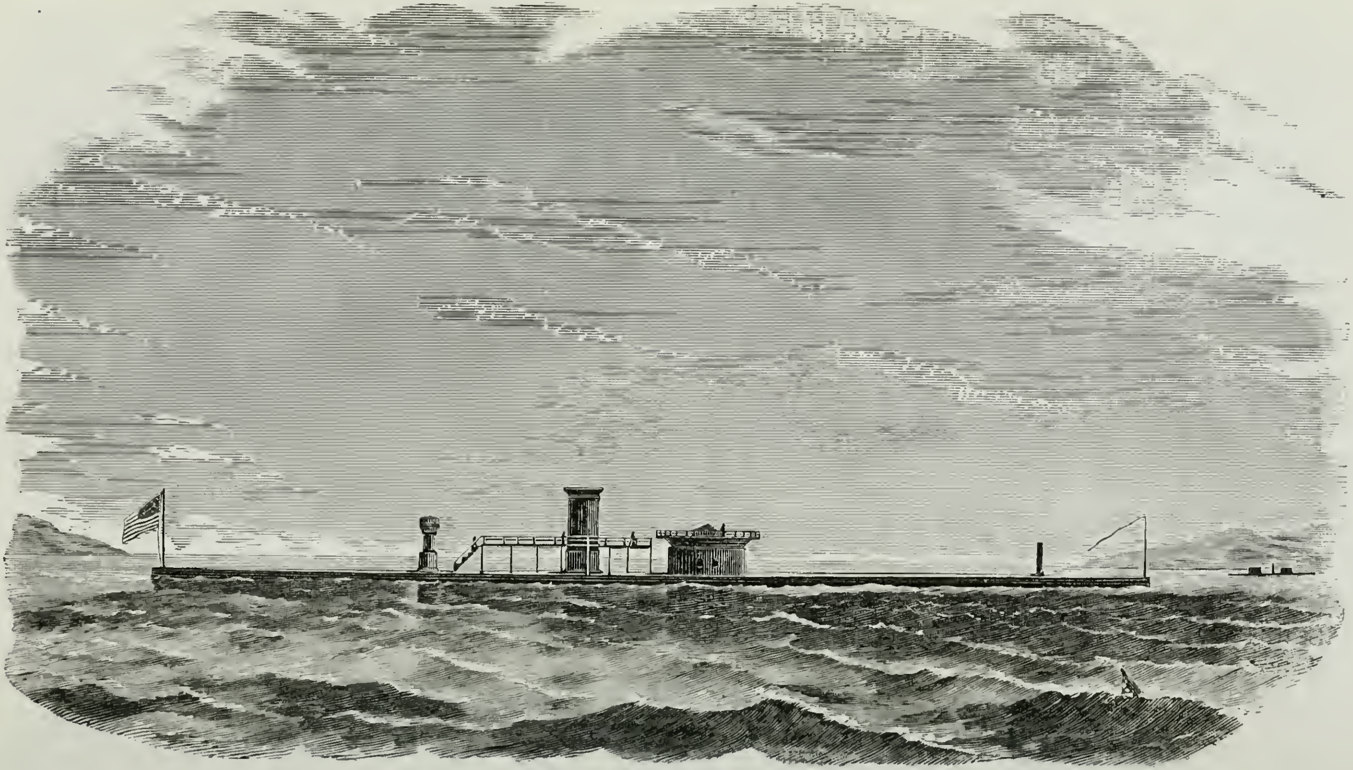


FIG. 1.
FIG. 2
FIG. 3
FIG. 4.
SCALE OF TONS
FIG. 5.
CURVE OF DISPLACEMENT.
SCALE OF FEET.
10
25
50
75

PLATE I.



immunity from liability to founder in consequence of injury to the hull. The hull is further strengthened by the bulkheads of the "turret chamber," which stiffen the whole structure by tying the decks, the coal bunkers, and the lower longitudinal bulkheaks firmly together.

The double bottom is not only made water-tight as a whole, but is divided into spaces of 32 feet in length each, separated by water-tight partitions, formed by caulking-frames and cross-floors.

The Stem of the vessel rises vertically, and is of a section ten inches by three. The cell-like construction of the vessel behind it, and the immense strength of this portion of the hull, will enable it to receive very heavy shocks without serious injury. The whole of this part may be torn away to a distance of thirty-five feet from the stem, by intentional or accidental collision, without endangering the safety of the vessel. Three of the partitions in the bow being horizontal formed by the extension of breast-hooks, back to the transverse bulkheads, a projectile may penetrate, or a seam may start, at any one point without doing other injury than to fill one of these small compartments with water.

The stern "overhang" is carried well out over the rudder, which it fully protects. It is prepared to receive armor plating like other portions of the vessel.

The outer skin is composed of selected boiler plate, which is stated to have been tested, as received under the inspection of an officer of the Government, and received only when found to have a tensile strength of 62,000 pounds per square inch of cross section. Its tenacity is at least 20 per cent. greater than that of iron customarily used in the construction of iron vessels by foreign builders.

The thickness of keel strake is one inch; the garboard strakes are five-eighths of an inch thick; the intermediate strakes are of half-inch iron, and the wale strakes aie three-quarters of an inch in thickness. The keel strake is double riveted, as are also the garboard and two wale strakes. The riveting has all been done by hand with both care and skill.

The inner skin is also of selected charcoal iron, of "C No. 1" quality, such as is generally used only for boiler plate. Its joints were all planed and fitted under the inspection and the direction of the Engineer in charge, and the workmanship is unexceptionable.

Its thickness is one inch for a distance of 193 feet amidships, ½ inch for a distance of 30 feet at the ends, and ¾ inch at the intermediate portions. It is double riveted fore and aft, with treble riveted buttstraps for 240 feet amidships. The inner skin is carried up to the fourteen feet line and is made water-tight throughout, as already stated, permitting the rupture of the outer skin without endangering the safety of the vessel. This, with the division of the whole into short water-tight spaces by caulking the frames, is an insurance against even loss of trim by the penetration of the water throughout the space between the two hulls.

The main deck is supported by heavy yellow pine deck beams, of scantling 14x14 and 16x14 inches, spaced usually 36 inches between centres. They rest, at each end, upon a heavy and very strong iron shelf, which serves also to strengthen the ship as a stringer. The beams are also secured to the skin of the vessel by strong iron knees, as seen in Plate VI. They are intended to be supported in the middle by a line of iron stanchions not yet in place. This deck is planked with selected Southern yellow pine, free from sap, shakes or other defects, and thoroughly seasoned. Its thickness is 8½ inches throughout.

MAIN ENGINES AND BOILERS.—GENERAL DIMENSIONS.

Number of Steam Cylinders	4
Diameter " "	72 inches.
Stroke of Piston	45 "
Surface Condensers, refrigerating surface	12,650 square feet.
Number of Screw Propellers	2
Diameter " "	18 feet.
Pitch " "	27 "
Number of Boilers	10
Area of Heating Surface	28,000 square feet.
" Grate "	876 "

The Main Engines are arranged in pairs, each of the two pairs driving a screw independently. Each pair has its own surface condenser and its own set of pumps, including a centrifugal circulating pump, driven by a small independent engine, taking steam from the main steam pipe. The main engines are of the vertical return connecting rod type, formerly known as the "Mandsley and Field Engine." They are shown, in Plates II, III, and IV, in side elevation and section in end elevation, and in plan.

This general design was decided upon as being at once compact, readily accessible, and convenient in operation, and as "stowing" well in a ship of which the form was too fine to admit of twin engines of other types. The steam cylinders are four in number, 72 inches in diameter, and having a stroke of piston of 3 feet 9 inches. The Main Valve is a balanced three-ported slide, having a maximum throw of sixteen inches. The valve is operated by a Stephenson

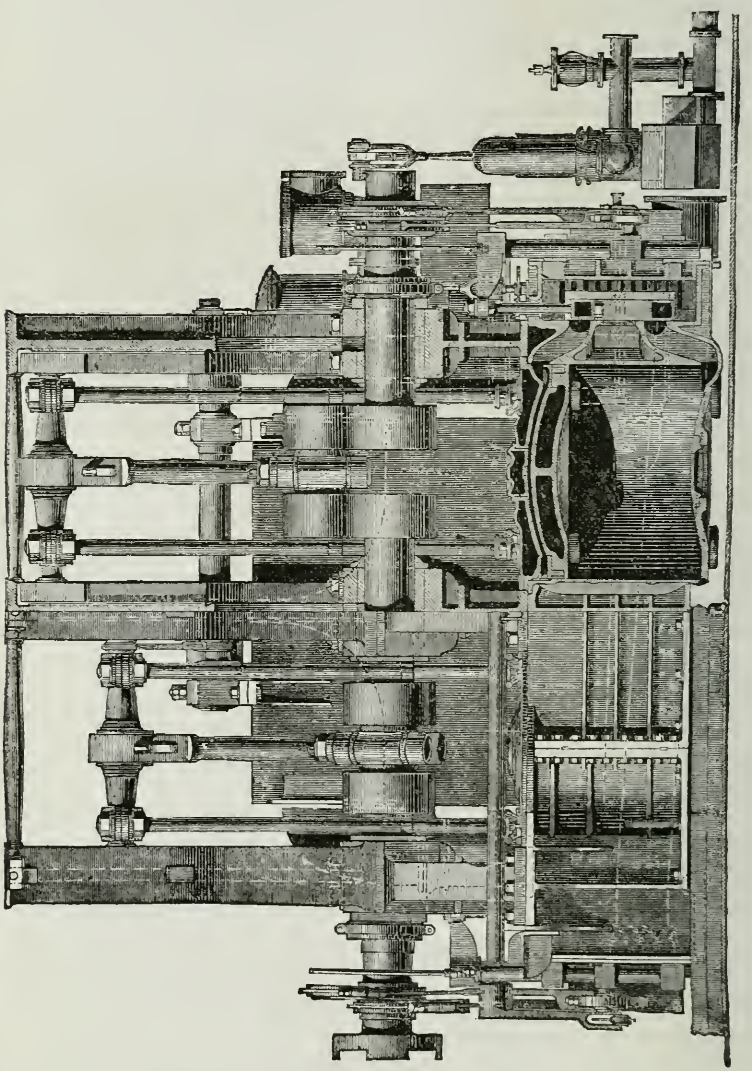


Plate II.

Link, as shown in Plate III. Expansion is obtained by means of a "gridiron" valve, situated at one side of the main valve chest, as shown in Plates II, III, and IV, and driven by its own eccentric. The

Connecting Rods are 7½ feet long, 7½ inches in diameter in the neck, and 8½ inches diameter in the middle. These rods, which seem to be as lightly proportioned as any part of the engine, have ample strength to resist any pressure which can be thrown upon them in regular work.* At their upper ends, they are fitted with straps, and are set up by means of the common taper key. At the lower end they have caps secured by bolts and nuts.

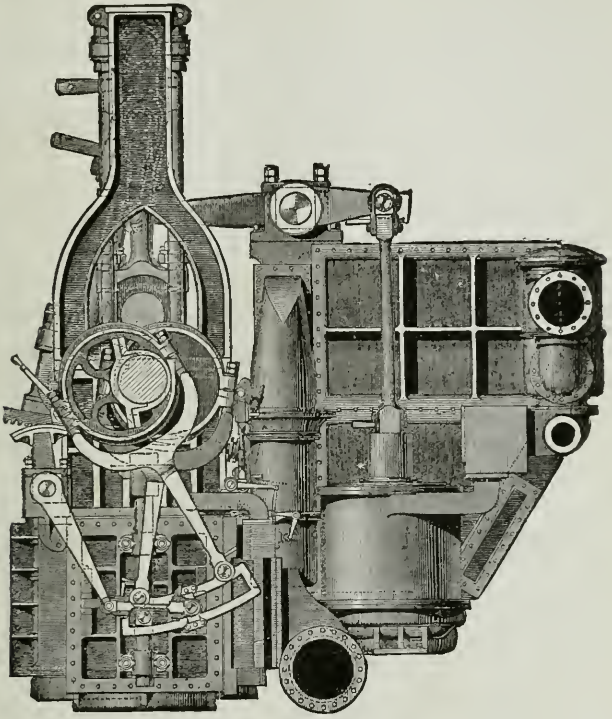


PLATE III.

*The proper size for such an engine is calculated, with a fair degree of approximation, by the formula . . .

$$d = \sqrt[4]{\frac{D^2\,p\,L^2}{6000}} + 0{\cdot}0125\,D\text{; or } d = \sqrt{\frac{D\,L\,\sqrt{p}}{8{\cdot}8}} + \frac{D.}{80}$$

This formula has been found by Professor Thurston to be a very satisfactory one. In the present case, $d = \sqrt{\frac{72 \times 7\frac{1}{2} \times \sqrt{15+25}}{8{\cdot}8}} + \frac{7}{8} = 7{\cdot}5$. Taking Van Buren's constants and Rankine's more intricate formula,

$$d = 0{\cdot}00527\,D\sqrt{p\left(1 + 0{\cdot}00133\,\frac{L}{D^2}\right)} \quad \text{we get,}$$

$$d = 0{\cdot}00527 \times 72 \times \sqrt{(25+15)\left(1 + 0{\cdot}00133\,\frac{90}{7{\cdot}4^2}\right)^{\cdot 2}} \times 8 = 7{\cdot}4 \text{ inches.}$$

The Crank Shafts are forged in three pieces, connected by crank-pins and cranks, which were forged separately, carefully fitted, and then forced together so firmly as to give all the rigidity of a single piece. The total length is 24 feet 9½ inches. The diameter of each crank-shaft is 16 inches. The intermediate bearing is 16 inches in diameter and 3 feet long. The end journals are 16 inches in diameter and 2½ feet long. The Crank Pins are of steel. Their journals are 15 inches in diameter and 15 inches long. They have ample strength and area of rubbing surface.*

A Surface Condenser is attached to each pair of engines. The tube-plates are in place, and the whole condenser is complete and in position, with the exception of the tubes. These are not ordered. The total area of refrigerating surface in each is designed to be 6,325 square feet, or a total for both condensers of 12,650 square feet. The ratio of this area to that of the heating surface of the boilers is $\frac{12650}{28000} = 0{\cdot}449$, of which the inverse ratio is 2·29, and the ratio of cooling surface in the condensers to the area of grate surface in the boilers is nearly 14½ to 1. This area is more than ample for the amount of work to be done. Each condenser is to contain 4,198 tubes, each 9 feet 6¾ inches long and ⅝ inch diameter. The position of the condensers may be seen in Plates III and IV.

The Engine Room occupies 35½ feet in the length of the vessel

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*The size of crank-pins required to prevent heating of the journals may be determined with a fair degree of precision by either of the formulæ given below

The total pressure on each crank-pin bearing would be at a maximum, 4071·5 × 25 = 101, 787·75 pounds.

$$l = \frac{P\ V}{60{,}000\ d} = 28{\cdot}8. \qquad \text{[Thurston, 1862.]} \qquad [1]$$

$$l = \frac{P\ (V+20)}{44.800\ d} = 41{\cdot}8. \qquad \text{[Rankine, 1865.]} \qquad [2]$$

$$l = \frac{P\ N}{350.000} = 18{\cdot}9. \qquad \text{[Van Buren, 1866]} \qquad [3]$$

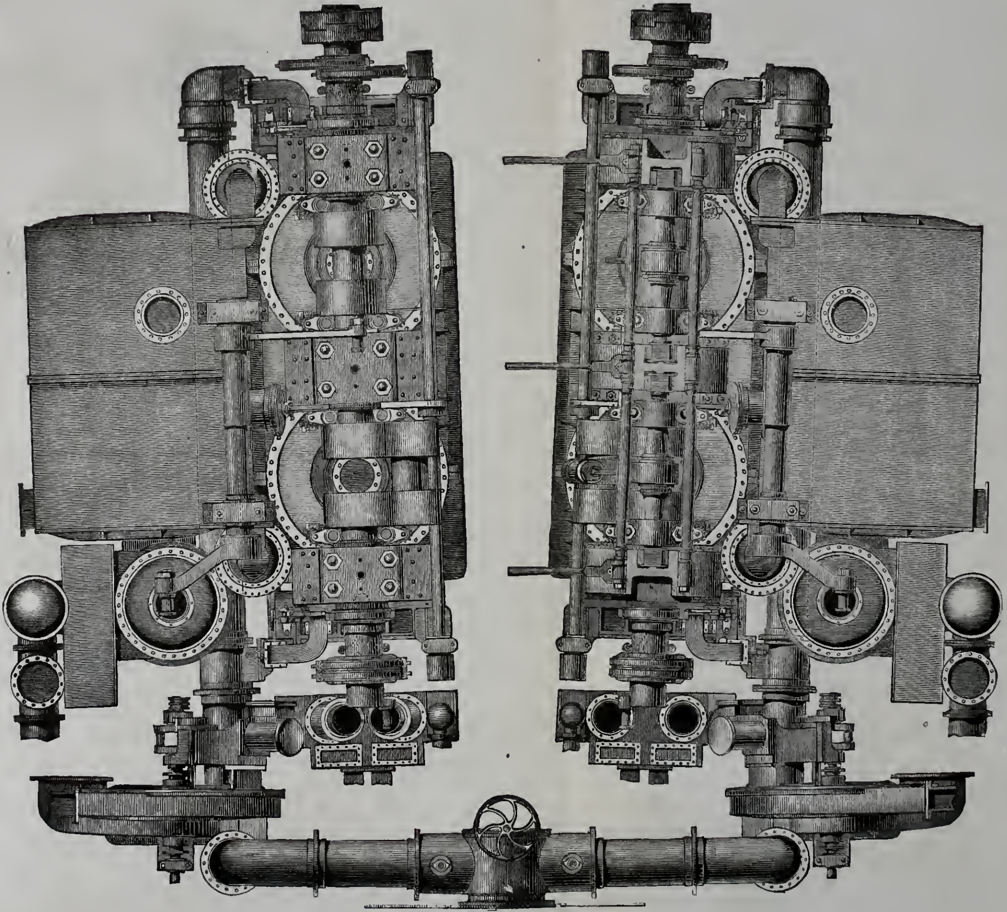
$$l = \frac{I\ H\ P}{130\ s} = 11{\cdot}6. \qquad \text{[Skeel, 1873.]} \qquad [4]$$

The first two formulæ give what are considered by their authors fair working proportions, and the last two minimum length, for iron pins.

Formula [1] was obtained by observation of crank pins of naval screw engines, and [2] by observing locomotive practice in which greater liability exists of annoyance by dust, and greater risk occurs from inaccessibility while running. The latter formula is therefore not well suited for marine practice.

Steel can usually be worked at nearly double the pressure admissible with iron running at similar speed, and the proper length for those here considered would be about $\frac{28{\cdot}8}{2} = 14{\cdot}4$, a length which they exceed. These pins should, therefore, run without water, a somewhat unusual thing with engines of large size.

Stevens Iron-clad Battery. Plate IV.



very nearly amidships. The directions of the shaft lines are divergent, as seen in the plan, Plate IV, their centre lines being 10¾ feet apart at the engines, and 16 feet 8½ inches at their outer ends, a divergence of 0·4366 inches per foot.

The Screws are of cast iron, and of the form shown in Plate V. They are three-bladed, "true screws," having a diameter of 18 feet, and a pitch of 27 feet. The length of hub is 3½ feet, its diameter 34 inches. The total area of each blade is 27·197 square feet, of each screw 81·59 square feet, and of each "screw disc," 254·47 square feet. The engines are arranged to turn them in opposite directions.

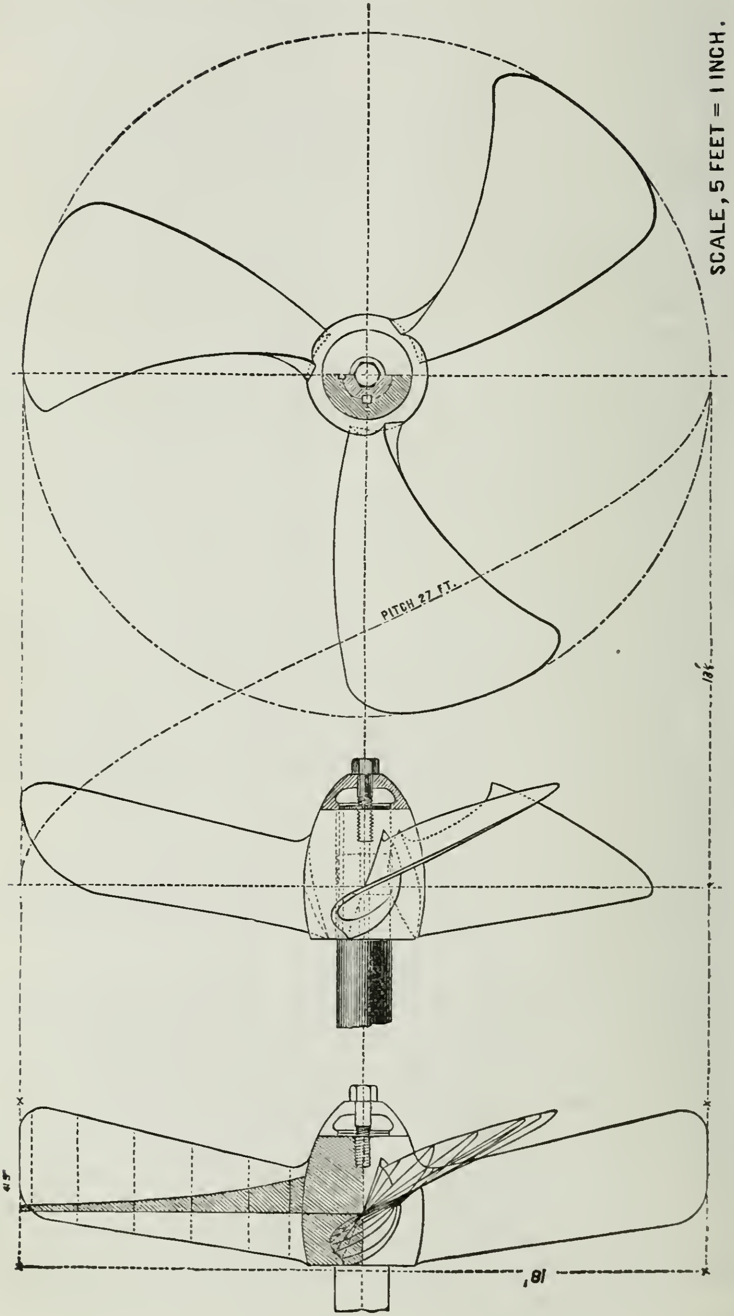
Blowing Engines and Fans are in place at the after end of the engine-room, and at the forward end of the boiler room. These fans are each 8 feet in diameter and are each driven by one engine having a steam cylinder of 16 inches diameter and 14 inches stroke of piston. Two very large blowers are also on hand and ready to be mounted in the space below the turret, where their driving engines are set up. They are 5 feet 2½ inches in diameter, and have a breadth of face of 3 feet 8½ inches. Their driving engines are single, with steam cylinders 16 inches diameter and 14 inches stroke of piston.

The Anchor Hoisting Engines have been completed and set up in their place over the chain locker, immediately abaft the armored bulkhead near the bow. The cylinders are 14 inches diameter and 14 inches stroke. The anchor hoister, or windlass, has not been built. A design was prepared, under the direction of the Consulting Engineer, by the late F. S. Thayer, of the Stevens Institute of Technology, which may be used, if considered suitable by the purchaser of the vessel.

All of this machinery was built from Mr. Newton's drawings by the Delamater Iron Works of New York, and the material and workmanship are of unusual excellence. All material was paid for by the pound, and at prices fixed by agreement.

The weight of engines and machinery, as above described, is 500 tons. There are ten steam boilers of the usual marine, horizontal, fire-tubular type, with furnaces and combustion-chambers below the tubes. The shell is rectangular in form, and well braced. These boilers are placed in one long fire-room, or "stoke-hole," and occupy 83 feet 8 inches in the length of the ship, the fire-room running fore and aft. Each boiler contains three furnaces, having a width of 3 feet 11 inches, and a height, including ash-pits, of four feet. No grates have been made. They are intended to be 8½ feet long in the

Plate V.



after, and 6½ feet in the forward boilers. The distance from the grate to the crown of the furnace is intended to be 23½ inches in front, and 30 inches at the back end.

The front of each boiler is 13 feet 10 inches in length, and 14 feet in height. The depth from front to rear varies from 11½ feet in six boilers, to 10 feet 1½ inches in the two forward ones; the depth in intermediate boilers being 11 feet. Each boiler contains 432 tubes of 2½ inches exterior diameter, and from 7 to 9 feet long. The upper row of tubes is six feet below the top of the boiler. The total area of grate surface is 876 square feet.

The heating surface has a total area of 28,000 square feet, distributed as follows:

Tubes	23,380	square feet.
Furnaces	2,050	" "
Connections	1,890	" "
Tube Sheets	680	" "
Total	28,000	" "

Ratio of heating to grate surface.....................32 to 1.

This high ratio of heating to grate surface should give great economy of fuel.

These boilers have been tested with cold water under sixty-six pounds pressure per square inch. Their total weight, including valves and pipes, is 255 tons.

The steam power of the boilers is sufficient to supply moderately economical engines of greater size than those to which they are to furnish steam. The range ordinarily observed in marine practice is from 2·5 to 5·0 feet of heating surface to each indicated horse-power, and from 0·1 to 0·2 square feet of grate surface for each horse-power, with forced draught.

Under such extreme conditions, these boilers would supply steam for from 5,600 to 11,200 I. H. P., if estimated by heating surface, or for 4,380 to 8,760 I. H. P., as estimated from the area of grate. The more favorable conditions are those exhibited in the best of recent practice in marine engineering; the less favorable are those of the practice of twenty years ago.

The coal bunkers are arranged in three groups,—abaft the engines, between the engines and boiler compartments, and forward of the boilers. They are made water-tight, and can be emptied and filled with water at pleasure. They have a total capacity for 800 tons of coal.

A forced draught is secured by making the fire-room air-tight and forcing in the air required to support combustion by means of the blowing apparatus already described. This method has been proven —if the personal experience of the Consulting Engineer on large naval steamers, etc., can be relied upon—to be much more effective and convenient, and far more comfortable than the old plan of leading the air directly to the ash-pits through closed pipes. This plan was introduced many years ago by the late Robert L. Stevens. It is now becoming frequently adopted.

With such proportions as have been given these boilers, and with the arrangements here adopted, a good result should be obtained with a consumption of twenty pounds of coal, or more, per square foot of grate per hour.

The total length in the ship occupied by engine and boiler-room is 119 feet 8 inches. The total weight of propelling apparatus and machinery is, approximately, the following:

Engines, shafts, screws	500	tons.
Boilers and attachments	255	"
Water in Condensers	25	"
" Boilers	200	"
Total	980	tons.

No steps have yet been taken in the construction of either armor or armament. It was proposed to cover the main deck with plating 1½ inches thick fore and aft.

The side armor is shown in section, in Plate VI, which also illustrates the construction of the armor shelf and backing, which are constructed and ready to receive the armor. The side armor is to surround the vessel, except at the bow. Thirty-five feet from the stem, a heavy transverse bulkhead meets the side armor and carries the same thickness of protecting plating,and a similar arrangement of backing. The thickness of armor plating proposed is ten inches from the level of the main deck down to a line four feet below, and thence five inches to the lower edge of the armor shelf.*

The backing is of wood, 44 inches thick. The inner course is of white oak, in heavy balks set on end, and thoroughly secured by a large number of bolts. The outer portion is of yellow pine timber laid horizontally and well scarphed together. The upper portion of the armor is also backed by the whole structure of the heavy main deck, against which the upper portion of the armor backing proper rests. The side of the vessel exposed above water can thus be made capable of resisting far heavier blows than it would be likely to receive in action from any guns afloat.

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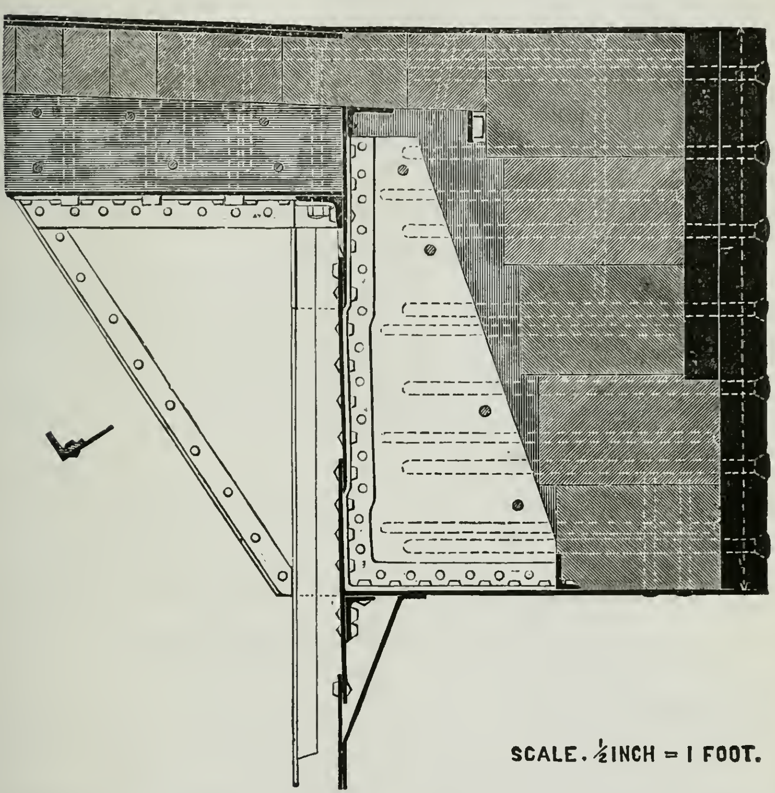
*The armor, as preferred by the Consulting Engineer, may be made considerably thicker where protecting the machinery and given a correspondingly reduced thickness at stem and stern.

As a security against decay, the backing has been saturated with crude creosote, which was shown by Professor Renwick, and which has been proven by subsequent experience, to be an effective defence against the teredo as well as against rot.

PLATE VI.



The turret has not been constructed, and no detailed plans have yet been prepared. A turret has been proposed thirty feet in diameter, and the Engineer has estimated on a thickness from 16 to 18 inches, the precise figure to be determined by the amount of other weight carried. The heaviest armor yet made abroad is 14 inches, and in our own navy 15 inches.

The guns first proposed were two XX-inch U. S. naval smooth-bored guns, weighing 95,000 pounds each, throwing a shot weighing 1,040 pounds, with a charge of 200 pounds of powder. Rifles of XII-inch bore, throwing shot of equal or greater energy, would probably be considered far preferable by the majority of ordnance officers. The energy of a shot of the latter description, on leaving the gun may be estimated at about 10,500 foot-tons, and its penetrating power is sufficient to destroy plating 17 and 25 inches in thickness, with and without backing respectively.*

SPEED AND ENGINE POWER.

The fine lines of this vessel should give a high coefficient of performance, and enable high speed to be attained with comparatively small power. In the following estimate, however, it has been assumed that the performance of the machinery and the efficiency of the vessel would not exceed that of average cases.

MODERATE STEAMING.

With 20 pounds of steam, "cutting off" at 0·4, which is very nearly the most economical point for such engines, allowing for imperfect vacuum and other usual losses of pressure, the mean pressure on the piston will be 20 pounds per square inch.†

At 60 revolutions per minute, with a mean pressure of 20 pounds, these engines would develop

$$\frac{\overset{-2}{72} \times 0{\cdot}7354 \times 20 \times 7\tfrac{1}{2} \times 60 \times 4}{33000} = 4442 \text{ I.H.P.}$$

With a coefficient of 225, the usual "displacement formula" gives

$$V = \sqrt[3]{\frac{\text{C.I.H.P}}{D^{\frac{2}{3}}}} = \sqrt[3]{\frac{225 \times 4442}{6006^{\frac{2}{3}}}} = 14{\cdot}46 \text{ knots}$$

as the probable speed.

---

*The penetrating power, as deduced by Professor Thurston in 1870 (*Journal Franklin Institute,*) is $t = \frac{\sqrt{W V^2}}{400.000\, d} = 17{\cdot}3$ for a backed plate, and one-half greater thickness, when unbacked, may be fractured.

†The mean pressure of steam in the cylinder of a steam engine may be determined for ordinary practice, such as is here considered, by the formula:

$$p = P\,\frac{1 + A \log \varepsilon}{\varepsilon} - B - C\,P;$$

in which p represents mean pressure, P the boiler pressure, and ε the ratio of expansion. The constants, as determined many years ago by Mr. Francis B. Stevens, are $A = 2{\cdot}3$; $B = 5$; $C = 0{\cdot}06$.

Taking C = 600 in the other, or "midship-section formula,"

$$V=\sqrt[3]{\frac{C.I.H.P}{M}} \text{ we obtain } V=\sqrt[3]{\frac{600\times 4442}{890}}=14{\cdot}41 \text{ knots}$$

Again taking the formula $V=\frac{1}{2}\left(\sqrt[3]{\frac{C.I.H.P}{M}}+\sqrt[3]{\frac{C'IHP}{D^{\frac{2}{3}}}}\right)$ using C = 600, C′ = 225, the estimate becomes 14·43 knots.

We should be justified probably, in taking higher coefficients of performance, since the quotient $\sqrt{\frac{\text{length}\times\text{breadth}}{\text{draught}}}=\sqrt{\frac{390\times 45}{22}}=6$, bears very nearly the most economical relation to the ratio $\frac{\text{length}}{\text{breadth}}=\frac{390}{45}=8{\cdot}67$ for vessels of great speed.

The lines of the vessel are unusually fair and fine, and may be taken for purposes of calculation as "wave lines."

The armor shelf will impede the vessel somewhat when "out of trim," but no reason exists for supposing that the Rankine method of computation will not apply to this case. The unusually large proportion of skin area to displacement will rather tell against the vessel. Adopting the method here referred to, the "wetted surface" of the hull is found to be very closely 22,462 square feet, at 22 feet draught, to which must be added the area of horizontal surface beneath the armor shelf, 3,060 square feet.

The "coefficient of augmentation," as deduced by measurement of the angle of greatest obliquity of the water lines, Plate 1, is

$$C=1+4\,\mathrm{Sin}^2\theta+\mathrm{Sin}^4\theta=1{\cdot}1$$

The "augmented surface" is therefore

$$22462\times 1{\cdot}1+3060=27768 \text{ square feet.}$$

The probable attainable speed, with 4442 indicated horse power is

$$V=\sqrt[3]{\frac{20{,}000\times 4{,}442}{27{,}768}}=14{\cdot}73 \text{ knots.}$$

The average of these estimated speeds is 14·5 knots, which may be considered to represent *the speed of the vessel without driving.* It should be readily attained, using eight boilers, and may be reached with but six.

The Slip of the screws, when steaming 14½ knots, with 60 revolutions of the engines, would be 9·1 per cent.

For vessels of fine lines and high speed, with well designed propelling apparatus, the slip has usually been estimated, by Professor Thurston, at four times the ratio of area of midship section to that of screw-disc. The total disc-area of these screws is $254·4 \times 2 = 508·8$ square feet, which is equal to $\frac{508·8}{890} = 0·57$ of the area of greatest immersed section, an unusually high ratio, and a proportion which should give great economy of propelling power. Using the rule above referred to, the slip would be estimated at $S = 4 \frac{M}{A} = 4 \frac{890}{509}$ $= 7$ per cent., a figure not often found, except with badly shaped vessels, which sometimes give "negative slip." This is as should be expected, since the vessel has double the screw disc area obtainable in ships with single screws. The estimates which have been given contemplate the possibility of thirty per cent. greater slip.

MAXIMUM SPEED, CONTINUOUS STEAMING.

The provision here made for forced draught should, as has been stated, enable 20 pounds of coal to be burned per hour on each square foot of grate, and the high ratio of heating to grate surface should insure economical use of fuel at exceptionally high rates of consumption. Steam can be furnished continuously to drive the engines 65 revolutions per minute, and 68 or 69 revolutions, with a mean pressure of between 25 and 26 pounds per square inch, and 6,500 indicated horse-power, giving a speed of 16½ knots, may be obtained for the periods of time during which clean fires can be kept. With a boiler pressure of 25 pounds, and expanding as before assumed, the mean pressure in the cylinder would be 23½ pounds. With this pressure, at the speed here taken, 65 revolutions per minute, the engines would develop

$$\frac{\overset{-2}{7}2 \times 0·7854 \times 23\tfrac{1}{2} \times 7\tfrac{1}{2} \times 65 \times 4}{33,000} = 5654 \text{ I.H.P.}$$

which power has a ratio to heating surface of boilers of $\frac{5654}{28000} = 0·202$, a ratio which is well inside of ordinary practice.

The maximum speed, assuming the maximum power to be but 5,654 indicated horse power, will be—

By augmented surface, $V_1 = \sqrt[3]{\frac{20,000 \times 5654}{27,768}} = 15·97$ knots.

By midship section, $V_2=\sqrt[3]{\frac{600\times5654}{890{\cdot}26}}=15{\cdot}62$ knots.

By displacement, $V_3=\sqrt[3]{\frac{225\times5654}{6006}}=15{\cdot}67$ knots.

The mean of these estimates may be taken as the probable *maximum speed for continuous steaming.* This is 15·75 knots. The slip becomes 8·895 per cent. slightly less than that obtained for 14½ knots, as it should be at the higher speed. No armored vessel in any navy has the speed here found for this ship, or approaches it. The fastest yet constructed has a sea-going speed at least a knot less, and the fleetest unarmored vessel in any foreign navy has less speed by three-quarters of a knot. The speed of 16½ knots, which is considered as attainable under most favorable circumstances, exceeds that of any recorded trial performance of even the British iron-clad "Monarch," the fastest of the fleet, by more than 1½ knots per hour.

Weights would probably be distributed as follows:

Hull (including bulkheads, etc.)	2,250	tons.
Machinery and Boilers	755	"
Coal	800	"
Stores and other weights	700	"
Armor (side and deck)	1,020	"
Turret and Pilot House	400	"
Guns	80	"
Total	6,005	"

The following is the Speed, Time, and Distance table, as estimated for the ship, at the draught, and with the co-efficients of performance as already given. The figures are given as a probably close approximation. Coal 800 tons:

Speed in Knots.	I. H. P.	Coal per hr. per I. H. P. lbs.	Hours Run.	Days Run.	Distance, Miles.
16	6000	2¾	109	4·67	1744
15	5000	"	130	5·41	4850
14	4000	"	163	6·78	2282
12	2000	3	299	12·46	3488
0	1200	3½	427	17·79	4270
8	800	4	560	23·33	4480
6	600	4½	876	29·82	5256

The present capacity of coal bunkers is here taken on the assumption that it will be preferred to devote all surplus displacement to floating the maximum amount of armor, since it is probable that no long voyage will become necessary at full speed.

At the speed considered most economical for a naval vessel between stations, 6 knots, the number of hours steaming would be 876, or, a run of thirty days could be made, accomplishing a distance of 5,256 miles without coaling. At this speed, the engines are estimated as consuming $4\frac{1}{2}$ pounds of coal per horse-power per hour, as such large engines would fall off greatly in economy when developing such low power.

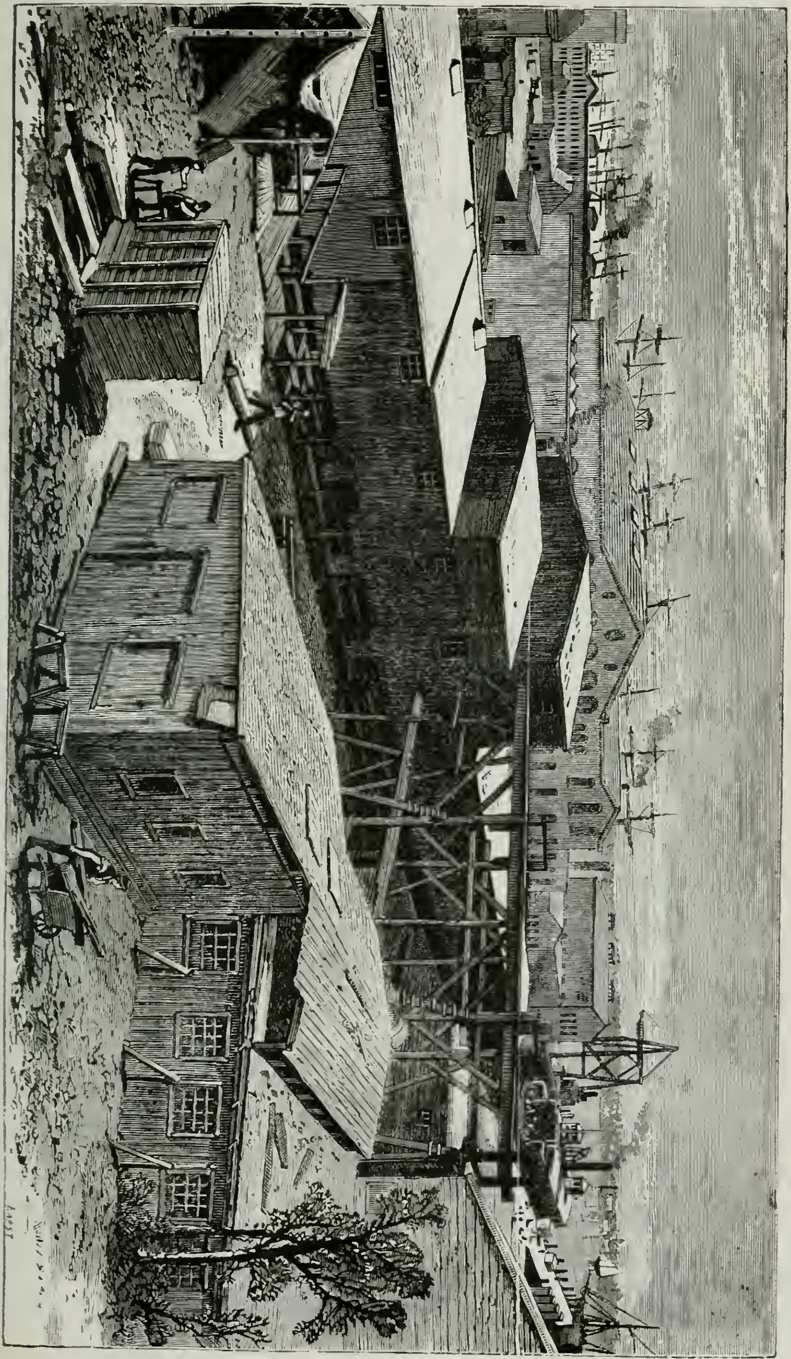
The lines of the vessel, and the form of the transverse sections, are calculated to give moderately easy motion in a sea-way. The stability is very great, and her motion would be quick, and somewhat uneasy if completed with high free-board. All vessels of the monitor class, however, are found to behave well in the heaviest seas, even when not peculiarly well shaped. The height of the metacentre above the centre of buoyancy, is 11·72 feet, and is 2·85 feet above the load line. The Moment of Stability at a heeling angle of 15 deg., is $6{,}000 \times 11{\cdot}72 \times 0{\cdot}2588 = 18{,}200$ foot-tons, a higher value than is often obtained. This great moment of stability is largely due to the projection of the armor shelf.

The strength of general structure, the peculiar construction of the bow, and the great power of the vessel, make it a very effective Steam Ram. Steaming at full speed, and striking another vessel at rest, the energy exerted would be $E = \frac{WV^2}{2\,g} = 60{,}000$ foot-tons nearly, or sufficient to raise the weight of the whole vessel ten feet. This is equal, in effect, to that of eight or nine 600-pound rifle, or six XX-inch round shot, discharged simultaneously on the same spot. It is more than equal to the estimated energy of the projectiles of four of the proposed "81 ton rifles," recently designed by the British Admiralty. Such a blow would crush in even the armor-plated sides of any iron-clad yet constructed. The "handiness" of the vessel gives a facility in manœuvering which is a most essential advantage in the "ram."

The vessel lies in a dry dock at Hoboken, N. J., separated from the Hudson River by a bulkhead.

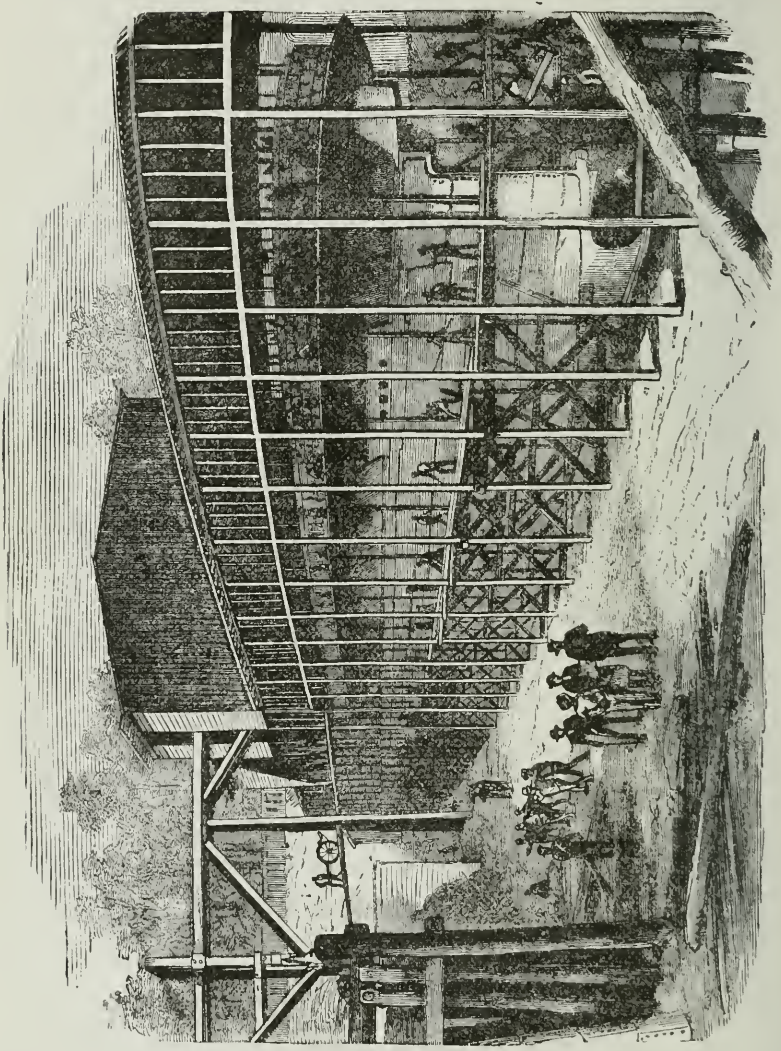
A machine shop is situated by the side of the dock, and several sheds which have been used for storage are within the enclosure. The city of New York lies directly opposite. The distance across the Hudson at this point is about 1700 yards.

PLATE VII.



The general arrangement of the premises, and the location, are well shown in Plate VII, which represents the vessel as seen from the southwest, and from a stand-point which gives a bird's-eye view. The

PLATE VIII.



vessel is covered by the ship-house seen in the middle ground, and is thoroughly protected against the action of the weather. The trestle frame, leading from the vessel amidships to the machine shop at the extreme right, has been used in transporting the heavy parts of the vessel and machinery. The slip into which the vessel emerges, on leaving the dry dock, is shown at the right, occupied by a ferry-boat.

The position of the ship in the dock is best shown in Plate VIII, which represents her appearance when nearly completed externally. The stand-point is taken under the stern at the bulkhead, at the end of the dock nearest the harbor, and the view extends to the bow, which lies under the street, running along the western line of the enclosure. The boarding has been removed from the sides of the house to afford a better view of the vessel. These engravings give so accurate an idea of the location of the vessel, and of the arrangement of the premises, that further description is unnecessary.

THE THEORY OF AERO-STEAM ENGINES.

By J. A. HENDERSON, M. E.

[Continued from vol. lxviii., page 113.]

In order to give a clearer idea of the precise mode of obtaining the results given in this table, the calculations in the case of example two are below indicated in full, as they were originally worked out by direct substitution of the data in the formulæ.

EXAMPLE TWO.

DATA.

$$P_1 = 60 \text{ pounds, } t_1 = 450^\circ \text{ and } N = 18 \text{ pounds.}$$

$$\therefore\ p_1 = 144 \times 60 + 2116{\cdot}4 = 10756{\cdot}4 \text{ pounds per square foot.}$$

$$r\,p = \frac{10756{\cdot}4}{2116{\cdot}4} = 5{\cdot}082 \text{ and } \tau_1 = 450 + 461{\cdot}2 = 911{\cdot}2^\circ$$

RESULTS.

$$\log.\ \tau_b = \log.\ 511{\cdot}2 + 0{\cdot}29 \log.\ 5{\cdot}082$$

$$\therefore\ \tau_b = 819{\cdot}1 \text{ and } t_b = 357{\cdot}9^\circ \ldots\ldots\ldots\ldots(1)$$

$$\log.\ r_c = 0{\cdot}71 \log.\ 5{\cdot}082$$

$$\therefore\ r_e = 3{\cdot}172 \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$t_h = \frac{10{,}000{,}000}{772(1+18) \times 0{\cdot}238} = 2864{\cdot}5^\circ \ldots\ldots\ldots\ldots(3)$$

$$t^c = 2864{\cdot}5 + 357{\cdot}9 = 3222{\cdot}4^\circ \ldots\ldots\ldots\ldots(4)$$

$$q_h = \frac{3222{\cdot}4 - 450}{450 - 357{\cdot}9} = 30{\cdot}102 \ldots\ldots\ldots\ldots(5)$$

$$w_e = \frac{1+18}{18} = 1.056 \text{ pounds,} \ldots\ldots\ldots\ldots (6)$$

$$q_w = \frac{0{\cdot}238\ (3222{\cdot}4 - 450)}{1124 + 0{\cdot}475 \times 418 - 100} = 0{\cdot}540 \ldots\ldots\ldots\ldots (7)$$

$$w_s = 0{\cdot}540 \times 1{\cdot}056 = 0{\cdot}570 \text{ pounds,} \ldots\ldots\ldots\ldots (8)$$

$$w_1 = 0.570 + 1{\cdot}056 = 1{\cdot}626 \text{ pounds,} \ldots\ldots\ldots\ldots (9)$$

$$v_a = 53{\cdot}15\ \frac{911{\cdot}2}{10756{\cdot}4} = 4.503 \text{ cubic feet,} \ldots\ldots\ldots\ldots (10)$$

$$v_s = 85\ \frac{911{\cdot}2}{10756{\cdot}4} \times 0{\cdot}57 = 4{\cdot}104 \text{ cubic feet,} \quad (11)$$

$$q_v = \frac{4{\cdot}104}{4.503} = 0{\cdot}911 \ldots\ldots\ldots\ldots (12)$$

$$v_1 = 4{\cdot}503 + 4{\cdot}104 = 8{\cdot}607 \text{ cubic feet,} \ldots\ldots\ldots\ldots (13)$$

$$\gamma_m = \frac{0{\cdot}238 + 0{\cdot}48 \times 0{\cdot}54}{0{\cdot}169 + 0{\cdot}37 \times 0{\cdot}54} = 1{\cdot}348 \ldots\ldots\ldots\ldots (14)$$

$$\frac{1}{\gamma_m} = 0{\cdot}741 \text{ and } \frac{\gamma_m - 1}{\gamma_m} = 0{\cdot}258$$

$$\log.\ \tau_2 = \log.\ 911{\cdot}2 + 0{\cdot}258\ (\text{a. c. } \log.\ 5{\cdot}082)$$

$$\therefore \quad \tau_2 = 599{\cdot}1^\circ \qquad \text{and} \qquad t_2 = 137{\cdot}9^\circ \ldots\ldots\ldots\ldots (15)$$

$$\log.\ r = 0{\cdot}741 \log.\ 5{\cdot}082$$

$$\therefore \quad r = 3{\cdot}336 \ldots\ldots\ldots\ldots (16)$$

$$v_2 = 3.336 \times 8.607 = 28{\cdot}71 \text{ cubic feet,} \ldots\ldots\ldots\ldots (17)$$

$$v_a = 53\ 15\ \frac{511{\cdot}2}{2116{\cdot}4} = 12{\cdot}84 \text{ cubic feet,} \ldots\ldots\ldots\ldots (18)$$

$$q_c = \frac{12{\cdot}84}{28{\cdot}71} = 0{\cdot}447 \ldots\ldots\ldots\ldots (19)$$

$$q_m = \frac{\dfrac{1{\cdot}348}{3{\cdot}336} - \dfrac{1}{5{\cdot}082}}{0{\cdot}348} = 0{\cdot}596 \ldots\ldots\ldots\ldots (20)$$

$$p_m = 0{\cdot}596 \times 10756{\cdot}4 = 6410{\cdot}8 \text{ pounds per square foot.} \quad (21)$$

$$q_n = \frac{\dfrac{1{\cdot}408}{3{\cdot}172} - \dfrac{1}{5{\cdot}082}}{0{\cdot}408} = 0{\cdot}606 \ldots\ldots\ldots\ldots (22)$$

$$p_n = 0{\cdot}606 \times 10756{\cdot}4 = 6518{\cdot}3 \text{ pounds per square foot.} \quad (23)$$

$$U^m = (6410{\cdot}8 - 2116{\cdot}4)\ 28{\cdot}71 = 123{,}296 \text{ foot pounds.} \quad (24)$$

$$U_n = (6518{\cdot}3 - 2116{\cdot}4)\ 12{\cdot}84 = 56{,}516 \text{ foot pounds.} \quad (25)$$

$$U_e = 124296 - 56516 = 66{,}780 \text{ foot pounds} \quad (26)$$

$$H_1 = \frac{10{,}000{,}000}{18} = 555{,}555 \text{ foot pounds.} \qquad (27)$$

$$H_2 = 555{,}555 - 66{,}780 = 488{,}775 \text{ foot pounds} \quad (28)$$

$$P_e = \frac{66{,}781}{28{\cdot}71} = 2{,}326 \text{ pounds per square foot,}$$

or 16·15 pounds per square inch..............................(29)

$$P_h = \frac{555{,}555}{28{\cdot}71} = 19{,}350 \text{ pounds per square foot,}$$

or 134·4 pounds per square inch..............................(30)

$$E = \frac{66781}{555{,}555} = 0{\cdot}120 \ldots\ldots\ldots\ldots (31)$$

$$C = \frac{1{,}980{,}000}{18 \times 66781} = 1{\cdot}647 \text{ pounds} \ldots\ldots\ldots (32)$$

It might be well to give an application of the last set of formulæ upon condensation, to illustrate the manner of their use, though the results were not thought of sufficient importance to be tabulated.

$$q_d = \frac{0{\cdot}540}{0{\cdot}911} \times \frac{85}{53{\cdot}15} = 0{\cdot}98 \ldots\ldots\ldots (33)$$

$$p_s = \frac{0{\cdot}98}{1{\cdot}98} \times 2116{\cdot}4 = 1030{\cdot}7 \text{ pounds per square foot,}$$

or 7·16 pounds per square inch..............................(34)

The required value of t_d corresponding to this absolute pressure, was found by reference to tables to be 177·84° Fahrenheit.

The only other example in which these calculations were made was the third, where $q_d = 0{\cdot}954$, $p_s = 7{\cdot}17$ pounds per square inch, and $t_d = 178{\cdot}35°$, the departure from the results of the previous case being but slight.

It should be stated that *almost all of the general formulæ from which these examples were worked out, are also applicable to aero-steam engines using any smaller proportions of air than the whole of the products of combustion;* only those relating to the determination of the separate weights of the air and steam, would have to be altered.

The remark might also here be made, as bearing upon these formulæ on weights as well as volumes, that for the purposes of any practical calculations, it would be coming down to an unnecessary degree of fineness to consider the relatively small quantities of water or aqueous vapor that may occur in the fuel or air furnished to the fire, and whose behavior in the products of combustion would scarcely differ from so much air.

In addition to the formulæ and examples thus far given, several other problems were investigated, whose general conclusions only need be referred to. The most important of them relate,

1. To the effect which would be had upon the work and efficiency of an aero-steam engine, were the air and steam conceived to expand in separate cylinders, their weights, initial pressures and temperatures, and final pressures, being the same as in the mixture ; and

2. To the determination of the size of the lifting air-pump for a condensing engine.

Another problem involves the determination of the efficiency of heating-surface of the fire-chamber and connections for injection of air in the boiler, in order to properly provide for the requisite transfer of the remaining heat, by ebullition through the water ; but its results more fitly belong with the discussion of the practical form of boiler, not entered upon in the present article.

About the second of these problems enough has been already said, while the practicability of using condensation was being considered.

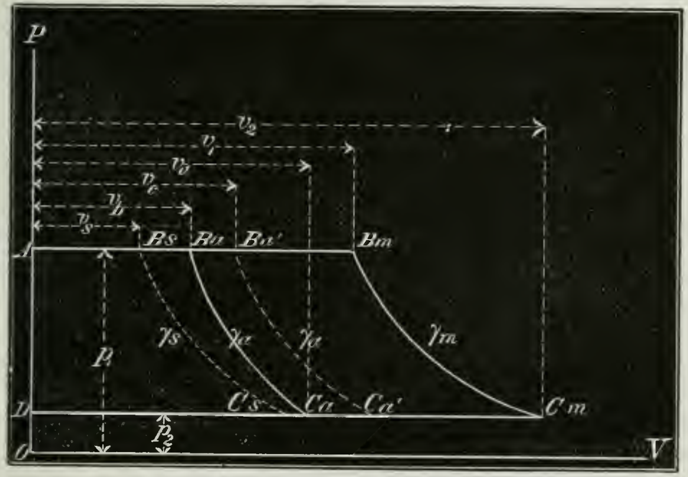
As the result of the first, it may be stated that in calculations made with the data of several of the previous examples, *the work developed by the separate expansion of the weight* w_a *of air and* w_s *of steam, from the common initial temperture* t_1 *and pressure* p_1 *to the atmospheric pressure* p_2, *was in every case the same as the work already found for the weight* w_1 $(= w_a + w_s)$ *of the mixture, expanding with the same values of* p_1, t_1 *and* p_2.

An independent proof of this equality of the work of the mixture to that of the component gases when worked separately under the same conditions as to limiting pressures and initial temperature, doubtless exists, but the essential difference in form between the working diagram of the mixture and that of either the air or steam, renders it difficult to see in any other way than by direct calculation that the equality holds true ; the equations of the curves of expansion, the ratios of expansion, and the final temperatures differ in each of the three cases.

A sketch of the theoretic form of diagram applicable to such an aero-steam engine as that under consideration, is represented upon the adjoining page, being a combined diagram of the main and pump cylinders. The corresponding angles are marked by the same letters *A, B, C, etc.*, which when the angles do not coincide, are indexed with the small initial letters of the respective fluids, while the proper values of γ are placed adjacent to the adiabatic curves of expansion. The coordinates of the angles are also given, being represented by the symbols for volumes and pressures used throughout the general formulæ.

As the whole cycle of operations has already been described for an engine using the mixture, the combined diagram explains itself and no further description is necessary.

The dotted curves of expansion B_s C_s and B_a' C_a', are introduced to complete the diagrams of the steam and air when expanded separately, according to the supposition of the problem just enunciated. The equality of work there indicated by numerical calculation, would be represented here by the equality of the area of A B_m C_m D, to the sum of the areas of A B_s C_s D and A B_a' C_a' D, the area A B_a C_a D of the compressing pump diagram remaining the same for the separate as for the mixed expansion. The effective work developed by an aero-steam engine using the mixture, and represented by the area B_a B_m C_m C_a, would be equal to that of a superheated steam engine having A B_s C_s D for its working diagram, added to that of a Joule's air engine having for its diagram of effective work the difference B_a B_a' C_a' C_a, between A B_a' C_a' D, and A B_a C_a D; this is equivalent to saying that the area B_a B_m C_m $C_a = $ area A B_s C_s $D +$ area B_a B_a' C_a' C_a,



These statements would seem to apply to any aero-steam engine whatever be the proportion of air admitted.

Previous to concluding our whole subject, some remarks need to be made upon the results hitherto arrived at, more particularly as relating to efficiency. A general explanation of the variation of the efficiency with different values of the data can be made in most cases independently of any direct calculations and may be fitly given prior to an examination of the numerical results of the examples.

By considering according to what has just been stated, the aero-steam engine to be equivalent to the combination of a super-heated steam engine and a Joule's air engine, the explanation may be much simplified, as in the separate engines the variations of work and efficiency can be readily followed out and the results then combined as being applicable to the aero-steam engine.

The quantities directly determining the resultant efficiency E of the mixture, are:

1. The proportion already given as q_h, in which the available heat of combustion is distributed between the steam and air, and which affects E by varying the relative amounts of the whole heat to which the separate efficiencies of the steam and air apply, and

2. The actual values of these separate efficiencies which may be denoted by E_s and E_a respectively.

The more important quantities upon which E is dependent, are the initial temperature t_1 the boiler pressure P_1 and the supply of air N per pound of fuel, which three data it will be remembered are the same as were made subject to change in the different examples.

Both q_h and the separate efficiencies, depend on t_1 and P_1, but q_h only is affected by changes in N. The variation of E with these data, may thus be expressed :

In all cases E increases with t_1 whatever values may be assigned to to P_1 or N. The variation of E with P_1 and N, depends not only upon the actual values of those quantities, but also upon the relation between P_1 and t_1, determining the range of temperature $t_1—t_b$ for the reception of heat by the air, as follows :

As long as P_1 is below, or t_1 above the limit necessary to keep $t_1 > t_b$ E increases directly with P_1, since E_s rises with the boiling-point, and also since E_a is increased owing to the whole reception of heat by the air being made to take place more nearly at the upper limit t_1. At the same time it (E) increases with N, because of the greater actual value of E_a over E_s for the same conditions as to pressures and temperatures. P_1 and N cannot however be advantageously increased together, as the more P_1 is increased, the smaller becomes the range $t_1 — t_b$, measuring the reception of heat by the air, and the larger must be the supply N, to cause E_a to have effect upon the resultant efficiency.

When P_1 is such that $t_b = t_1$, E is independent of N, and the air merely acts as a purveyor of heat from the fire to the steam. E is then the efficiency of steam E_s, under the given values of P_1, t_1 and P_2.

If P_1 be still further increased or t_1 diminished, the range $t_1 - t_b$ becomes negative, indicating that a portion of the heat of compression enters the steam. The efficiency of the steam would continue to increase with P_1, because of the elevation of the boiling-point, and of this addition of heat of compression; on the other hand, the air would not only perform no effective work at all, but would absorb a portion of that of the steam, owing to the resistance of the compressing pump exceeding the work re-developed by the air in the main cylinder. In this case the resultant efficiency E of the mixture, according to Professor Rankine's remarks (as well as the numerical results of the present examples,) increases both with P_1 and N varied either singly or together, the rate of increase with the latter being directly dependent upon the range $t_b - t_1$.

We may cause E to approach either E_a or E_s, by the following changes:

When E_a is desired to predominate, P_1 is reduced or t_1 increased to extend the range $t_1 - t_b$. and N is increased; by this means the proportion of heat using the air as its medium for conversion into mechanical energy, will be increased, and the resultant efficiency more nearly approach that of a Joule's air engine.

On the other hand, to cause E to approach E_s, either P_1 is increased or t_1 reduced, to diminish the range $t_1 - t_b$. The same effect might be produced by diminishing N, but the limiting case of $E = E_s$ can be reached by making $t_b = t_1$ whatever be the value of N.

In order that the most important quantities determined in the numerical examples, may be still more readily compared with one another, and in each case the effects of the change in the data directly observed with the greatest facility, the following tabular statement was condensed from the more complete one already given.

The calculated quantities which may be selected as being of most importance and interest are:

E, the resultant efficiency of the fluid, (and furnace combined,) or C the consumption of fuel per horse-power per hour, either of which measures the economy of the engine; P_e, the mean effective pressure in pounds per square inch, measuring the compactness of the engine for a given power; and q_c the ratio giving the size of the compressing pump cylinder, relatively to that of the main cylinder when both are single or both are double acting.

As before, only the three variable data used in the discussion of the variation of the resultant efficiency, are introduced.

Ex. No	DATA.			RESULTS.			
	P_1	t_1	N	E	C	P.	q_c
1	32·63	450	18	0·098	2·01	11·98	0·40
2	60·	450	18	0·120	1·65	16·15	0·45
3	100·	450	18	0·133	1·49	19·63	0·49
4	100·	600	18	0·162	1·22	21·59	0·44
5	100·	450	54	0·135	1·47	9·99	0·74
6	60·	600	54	0·183	1·08	11·33	0.61

The values of the data t_1 and P_1 were determined by the following considerations:

A temperature of 450° Fahr. was thought to be about the limit to which the mixture might be superheated and used with ordinary forms of steam cylinders. Where 600° is reached special arrangements may have to be made for protection against heat, either by jacketing the cylinder with the feed-water, or by adopting some of the plans commonly used in air engines. The temperature of 600° is exceeded in several of the air engines discussed by Rankine, even where the available heat has to be conducted through the cylinder walls. When it is considered that the aero-steam engine can be made to possess all of the advantages in the direct use of the heat of combustion, common to the modern furnace gas engine, with a strict regulation of the upper limit by the water, and freedom of the working mixture from ash particles, it is probable that arrangements may be made to increase t_1 considerably beyond 600°.

The pressure P_1 is limited by t_1, for the reason that if t_b exceed t_1 too largely, the heat of compression would exert a destructive action on the pump, unless perhaps, at the expense of a certain loss in efficiency, the pump were jacketed with cold water and its temperature kept down. P_1 is also practically determined by the form of boiler, which cannot be divided up into tubes, as is desirable for very high pressures. 100 pounds per square inch above the atmosphere was chosen as a moderate limiting value.

By examining the table, it will be seen that throughout the first three examples t_1 and N are maintained the same, and P_1 alone is successively increased. In the second example, the increase of P_1 from 32·63 to 60 pounds is accompanied by an increase in E, as has already been explained should be the case, as well as a considerable one in P_e and a slight one in q_c. In the third where P_1 reaches 100 pounds, the changes observed in the second all become more marked. A comparison of the fourth with the third shows the result of increasing t_1 from 450° to 500°; the effects are even more favorable than those caused by the increase in P_1, as in addition to an increase in both E and P_e, q_c is reduced.

In the fifth, P_1 and t_1 remaining as in the third, N is increased from 18 to 54 pounds (just three times) but the change is decidedly a disadvantageous one, for while the gain in efficiency is practically insignificant, being less than 2 per cent., P_e is reduced one-half notwithstanding P_1 remains at 100 pounds, and q_c is increased in the ratio of about 3 : 2.

The sixth example is taking the direction of Joule's air engine, as the range t_1 t_p is so far increased by reducing P_1 to 60 pounds with t_1 at 600°, while N remains at 54 pounds, that the efficiency of the air is given predominance; as might have been anticipated, P_e is reduced with an increase in q_c.

The following are the conclusions arrived at, concerning the most advantageous use of mixed air and steam in the engine under discussion:

1. *When* t_1 *is required to have a moderate value,* so that the effects of heat need not be provided for, *comparatively high values of* P_1 *with the least possible supply of air* N, *are the most advantageous as yielding the highest efficiency consistent with the given temperature, in addition to high mean effective pressures, with moderate size of pump.* The case is well illustrated by the third example. When preparations are made for the use of high temperatures, two additional cases arise.

2. *If at the same time with high efficiency, a high mean effective pressure and small pump are desired to be retained,* P_1 *must remain at a high value, and* N *be kept reduced as far as possible.* This case is equivalent to the proceeding one with an elevation of t_1, as in example four.

If the very highest efficiency be required at the expense of an increased bulkiness of the engine, P_1 *may be reduced and* N *increased* as was done in example six.

The value of E in the first two of these three cases, is essentially that of superheated steam, but in the last it approaches that of air as worked in a furnace gas-engine. Even with the use of moderate limiting temperatures as in example three, the calculated value of E largely exceeds that of any steam engine discussed in Rankine's treatise, where the efficiency of the furnace is included. The least theoretical consumption C of coal there given for an engine using steam superheated to 428°, was about 2 pounds, whereas in example three, C calculated upon the same total heat of combustion, i. e. 10,000,000 foot pounds, falls to 1·49 pounds. With the higher value of 600° for t_1, in the fourth example, C is reduced to about $1\frac{1}{4}$ pounds and in the sixth to only 1 1-10 pounds. In this example by slightly further diminishing P_1 or increasing N or t_1, C might be reduced to one pound or less, and still preserve a mean effective pressure of about 10 pounds, including the resistance of the pump (or more than 20 pounds excluding this resistance ;) a combined result that has not been approached in any of the furnace gas-engines so far constructed.

It might be thought essential for the completion of the general problem of this engine, to give a larger number of examples embracing a wider range of data, but upon closer inspection it will be seen that those already discussed cover all necessary ground, especially when it is considered that by the *à priori* reasoning previously given, the results of any changes in the data capable of being largely varied, may be closely anticipated.

In order, however, to impart more concise ideas as to the leading dimensions as well as gross consumption of fuel of aero-steam engines of this class, there may be here introduced with propriety a short application of the results of a few of these examples to as many cases of actual engines, while working according to their data and exerting different given amounts of power.

The best examples to illustrate are probably the third, fourth and sixth, which have just been cited as being typical of the three courses open to advantageous change in the data. Let us thus take the cases of:—

1. A large single cylindered marine engine, to exert 1000 indicated horse-powers, while making 50 revolutions per minute and working according to the data of example three.

2. A locomotive with two cylinders indicating a power of 200 horses and making 150 revolutions while fulfilling the conditions of example four ; and

3. A small single-cylindered stationary engine of 10 horse-powers, running with a speed of 80 revolutions, as illustrative of example six.

The quantities to be determined are V_m and V_n, the respective volumes in cubic feet of the main and pump cylinders when both are double acting, and C_1 and C_t the consumptions of coal by the engine in pounds per hour, and tons per day, respectively.

Denoting by the symbols P and R, the number of horse-powers and rate of revolution per minute of the engine, and referring to the general formulæ or examples, for the values of W_e, P_e, v_2, v_a, q_c and C, we may directly see that

$$V_m = \frac{33000\ P}{2R \times U_e} \times v_2 = \frac{33000\ P}{2\ R\ P_e} \text{ cubic feet.....} \quad (a)$$

$$V_n = \frac{33000\ P}{2R \times U_e} \times v_a = q_c\ V_m \text{ cubic feet.......} \quad (b)$$

$$C_l = C \times P \text{ pounds..................} \quad (c)$$

$$C_t = C \times P \times \frac{24}{2240} = \frac{3 \times C \times P}{280} \text{ tons.........} \quad (d)$$

It should be noticed that the first common factor in the second members of both equations (a) and (b,) is the number of pounds of air admitted to the engine for each stroke of the piston.

The table given below embraces the application of these formulæ to the three cases proposed, and includes besides their principal data and direct results of calculation, three additional columns of the equivalent dimensions of the main and pump cylinders, whose diameters d_m and d_n, and common stroke s, are expressed to the nearest inch.

TABLE OF APPLICATIONS OF EXAMPLES.

Case No.	Data of Engine.			Data of corres. Examp.			Results of Prev. calculations.			FINAL RESULTS.						
	P	R	$\frac{s}{d_m}$	P_1	t_1	N	P_e	q_c	C	V_m	V_n	d_m	d_n	s	C_l	C_t
1	1000	50	1	100	450	18	2826	0·491	1·489	116·78	57·22	64	45	64	1489·	15·95
2	200	150	1·5	100	600	18	3109	0·444	1·222	3·538	1·571	17	11	26	244·4	2·62
3	10	80	2	60	600	54	1631	0·612	1·082	1·265	0·774	11	9	22	10·82	0·116

Both d_m and S were at once determined from V_m by assuming the ratio $\frac{S}{d_m}$, entered among the data in the table, while d_n was computed from V_n after having found S.

In the second case, that of the locomotive engine, the calculated volumes and dimensions apply to one only, of each of the two equal pairs of main and pump cylinders; the gross consumption of coal is that for the whole engine.

Where either the main cylinder or pump is to be single instead of double acting, in order to perform an equal amount of work at the same rate of revolution of the engine, its volumeas obtained from this table must of course be doubled, or if the ratio of the stroke to the diameter remains as before, these latter linear dimensions must be increased in the proportion of $\sqrt[3]{2}$ (= 1·26 nearly) to 1.

Any further comment upon this last set of applications is here unnecessary, as beyond what has already been spoken of in connection with the more general numerical examples, the tabulated results at once explain themselves.

It will be observed by a comparison with the results of actual practice, that in the aero-steam engines here illustrated there are to a great extent combined both the economy in fuel of the furnace gas-air-engine, and the compactness of the ordinary steam engine.

It may also be mentioned that the boilers for such engines admit of being made much smaller than those required for steam engines of the same power, not only because of the absence of waste chimney heat, but also because of the greater facility for imparting heat to the steam by the direct injection of the products of combustion into the water.

The values of the resultant efficiencies of these aero-steam engines that can be practically obtained, will of course be less than those calculated by the formulæ of this article on account of the latter not considering the efficiency of the mechanism, together with such losses as are caused by external radiation of heat, back pressure, incomplete expansion, etc., but in well constructed engines these losses may be so far reduced as not to seriously affect the efficiency, a conclusion that receives confirmation through the nearness of approach of the theoretical results of Professor Rankine's formulæ on steam and air, to those of actual practice.

The large loss arising from condensation in the cylinders of common steam engines, and caused by the readiness with which wet steam imparts its heat to the cylinder walls, is almost wholly prevented in the aero-steam engine. The prevention of such loss has been practically shown in Mr. Warsop's experiments to constitute one of the great advantages in the use of mixed air and steam.

Regarding the condensation that is liable to occur in the latter part of the expansion of the mixture, even when there is no loss of heat whatever by external conduction, it may be further stated that in those cases where this liquefaction takes place at all, because of the initial temperature not being sufficiently high for the ratio of expansion, the liberation of latent heat would theoretically somewhat more than compensate the pressures and volumes of the mixture for the loss in weight of steam, and would so cause the diagrams as calculated upon gaseous expansion to be really a little smaller if anything than the actual ones; the curve of expansion would be affected to a slight extent before the first actual condensation, as steam departs from the laws of a perfect gas sometime before becoming saturated.

It may at first sight appear a little strange that the resultant efficiency is thus directly increased where this condensation occurs, but when it is remembered that the latter is brought about through the increase of the initial pressure of the mixture as compared with its initial temperature, and that such a change is advantageous to the efficiency according to the general remarks previously made upon superheated steam, the fact may be fully accounted for.

The foregoing article embraces a general discussion of the theory of aero-steam engines utilizing the whole products of combustion, as far as it has been at present worked out by the writer, and is published with the desire that its results and conclusions may be the cause of leading to further inquiry into the whole subject, both upon the basis of theory, and if possible of experiment.

CHESTER, PA., Feb. 28th, 1874.

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THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. RICHARDS, Mechanical Engineer.

[Continued from vol. lxviii., page 122.]

FORGING.

Workshop processes that can be systematized are the most easy to learn. When a process is reduced to a system it is no longer a subject of special knowledge, but comes within general rules and principles that will enable a learner to use his reasoning powers to a greater extent in mastering it.

To this proposition another may be added that shop processes may be systematized or not, as they consist in duplication, or the performance of operations repeatedly in the same manner. It has been shown in the case of patterns that there could be no fixed system as to their quality or the mode of constructing them, and that patterns and pattern making were matters of special knowledge and skill, and in this respect to be distinguished from other branches of machine construction that could be systematized.

The same rule applies to forging but in a different sense. Unlike pattern making or casting, the general processes in forging are uniform; and still more unlike pattern making or casting, there is a measurable uniformity in the articles produced by forging, at least in machine forging, where bolts, screws and shafts are continually duplicated.

A peculiarity of forging is that it is a kind of hand process where the judgment must continually direct the operations, one blow determining the next, and while the pieces forged may be duplicates there is not uniformity in the manner of producing them. Pieces may be shaped at a white welding heat or at a soft red heat, by one or two strong blows or by a dozen lighter blows, the whole being governed by the circumstances of the work as it progresses.

A smith may not, throughout a whole day, repeat an operation precisely in the same manner, nor can he, at the beginning of an operation, tell the length of time required to perform it, nor even the precise manner in which he will perform the operation. Such conditions are peculiar and apply alone to forging.

I think proper to point out these peculiarities not so much from any importance they may have in themselves, but to suggest critical investigation and to dissipate any preconceived opinions of forging being a simple matter, easy to learn and involving only commonplace operations.

The first impressions that an apprentice forms of the smith's shop as a department of an engineering establishment is that it is a black, sooty, dirty place where a kind of rough unskilled labor is performed, a department that does not demand much of his attention. How far this estimate is wrong will appear in after years when experience has demonstrated the intricacies and difficulties of forging, and when he finds that the skill in this department is harder to obtain and costs more relatively than in any other. Forging as a branch of work requires in fact the highest skill and is one where the operation continually depends upon the judgment of the workman, which neither power nor machines can to any extent supplant.

The soot, hard labor, and heat, deter men from learning to forge, and create a preference for the finishing shop which makes a disproportion between the number of smiths and finishers.

Forging includes the forming and shaping of the malleable parts of machinery, welding or joining pieces together, the preparation of implements for forging and finishing, the tempering of steel tools, and usually case-hardening.

Considered as a process, forging may be said to relate to shaping material by blows or compression when it is rendered malleable by heating.

So far as hand tools and the ordinary hand operations in forging go, there can be nothing said that will be of much use to a learner; in all countries and for centuries past hand implements for forging have remained the same, and if the reader is not familiar with them already he has only to visit any machine forging shop where he will see samples and types of forging tools. There is no use in describing tongs, swages, anvils, punches, and chisels, when there is nothing in their form nor use that is not seen at a glance; but the tools and mechanism for the application of motive power in forging processes deserve careful notice.

Forging machinery consists in rolling mills, trip hammers, steam hammers, drops, and punches, with furnaces, hearths and blast apparatus for heating. The general characteristic of all forging machinery is that of a great force acting throughout a short distance; very few machines, except the largest hammers exceed a half inch of working range and in the average operations not one tenth of an inch.

These conditions of short range and great force are best attained by what may be termed percussion machines, that act by blows instead of slow or gradual pressure, and hence we find that hand and power hammers are the most common tools of the smith's shop.

To exert a powerful force that acts but a short distance, percussive devices are much more effective and simple than those acting by maintained or direct pressure; a hammer head may give a blow equal to a dozen tons by its momentum and absorb the reactive force which is equal to the blow; but if an equal force was to be exerted by screws levers or hydraulic apparatus the apprentice can easily see that an abutment would be required to withstand the reactive force and that such an abutment would require a strength perhaps beyond what ingenuity could devise.

This principle is somewhat obscure and the nature of percussive forces not generally considered; as may be illustrated by investigating the action of a simple hand hammer.

Few people in witnessing the use of a hammer, or in using one themselves, ever think of it as an engine giving out tons of force, concentrating and applying power by functions which if performed by other mechanism would involve trains of gearing, levers or screws; and that such mechanism if employed instead of hammers must lack that important function of applying force in any direction that the will may direct.

A simple hand hammer is in the abstract one of the most intricate of mechanical agents, that is, its action is more difficult to analyze than that of many complex machines involving trains of mechanism; but our familiarity with hammers makes us overlook this fact and the hammer has even been denied a place among those mechanical contrivances to which there has been applied the mistaken name of 'mechanical powers.'

Let the reader compare a hammer with a wheel and axle, inclined plane, screw or lever, as an agent for concentrating and applying power, noting the principles of its action first and then considering its universal use, and he will conclude that if there is a mechanical device that comprehends distinct principles, that device is the common hammer; it seems indeed to be one of those things provided to meet a human necessity and without which mechanical industry could not be carried on. In the manipulation of nearly every kind of material, the hammer is continually necessary in order to exert a force beyond what the hands may do, unaided by mechanism to multiply their force. A carpenter in driving a spike requires a force of from one to two tons, a blacksmith requires a force of from five pounds to five tons to meet the requirements of his work, a stonemason applies a force of from one hundred to one thousand pounds in driving the edge of his tools; chipping, calking, in fact nearly all mechanical operations consist more or less in blows, and blows are but the application of an accumulated force expended throughout a limited distance.

Considered as a mechanical agent the hammer concentrates the power of the arms and applies it in a manner that meets the requirements of the work. If great force is needed a long swing and slow blows accomplish tons; if but little force is required a short swing and rapid blows will serve; the degree of force being not only continually at control, but the direction at which it is applied also. Other mechanism, if used instead of hammers to perform the same duty, would from its nature require to be a complicated machine and act in but one direction or in one plane.

Another peculiarity of the hammer is that its acting range is continually graduated to the resistance that is opposed; in driving a stake or pile, for example, if it were performed by screws, levers, wedges, or any of the ordinary mechanism for concentrating force, a certain amount of movement in the motive power could only produce a proportionate movement of the stake or pile, and as it would be impossible to predicate the motive force upon anything so irregular as the resistance of the stake, there would occur a great loss of power and movement; with a hammer, however, the power is all expended in the performance of the work, the working range or the distance through which the hammer moves an object that is struck, is always as the resistance offered.

These remarks upon hammers are not introduced here as a matter of curiosity, nor with any intention of following mechanical principles beyond where they will explain actual manipulation, but as a means of directing attention to percussive agents generally, with which forging processes have an intimate connection.

Machines and tools operating by percussive action although they comprise a numerous class, and are applied in nearly all mechanical operations, have never received the amount of attention in text books that the nature of such machines calls for, nor their extensive use warrants. Such machines have not even been set off as a class and treated of separately, although the distinction is quite clear between machines with percussive action, and those with what may be termed direct action: both in the manner of operating and in the plans of their construction.

There is, of course, no lack of formulæ for determining the measure of force, and for computing the dynamic effect of such machines when acting against a measured or assumed resistance, and so on, but this is not what is meant. There are certain conditions, such as the strains that fall upon supporting frames; the effect produced upon malleable material when struck or pressed, and especially such conditions of work to be performed as will render one or the other of these classes of machines most applicable; these have received but little explanation that is of value to practical men.

To follow this distinction between machines and tools that operate by blows and those with direct action: The first impart force by the momentum of a moving mass that accumulates force throughout a long range, and expends the sum of this accumulated force on the object, the reactive force being absorbed by the inertia of the mass that gave the blow; the machinery required in the operation being only a weight, means to guide or direct it, and some means of connection with the motive power. Take a hand hammer for example, it accumulates and applies the force of the arm and performs all the functions of a train of mechanism, yet consists only of a small block of metal and handle to guide it.

In machines with direct action such as presses, shears, or rolls, there is required first a train of mechanism of some kind to reduce the motion from the driving power so as to attain force; next this force when exerted must be balanced or resisted by strong framing and powerful shafts; a punching machine for example, must have framing strong enough to resist an upward thrust equal to the force applied to the work, and the frames are always a huge mass, disposed in the most advantageous way to meet and sustain this reactive force, while a 'drop' that is capable of exerting an equal force, aside from the block consists only of a pair of slim guides to direct its course.

Leaving out problems of mechanism, although one of the first importance in forging machines, the adaption of pressing or percussive processes is mainly governed by the size and consequent inertia of the pieces acted upon. In order to produce a proper effect, that is, to start the particles of a piece throughout its whole depth at each blow, a certain proportion between the hammer and the piece must be maintained. For heavy forging this principle has led to the construction of enormous hammers for the performance of such work as no pressing machinery can be made strong enough to perform, although the action of such machinery in other respects would best suit the conditions of the work.

TRIP HAMMERS.

Trip hammers used in forging, bear a close analogy to, and were, no doubt, first suggested by hand hammers. They are the oldest of power forging machines and extensively used at this time; it will therefore be proper to notice them before steam hammers.

As remarked in the case of other machines that have been treated of, there is no use of describing the mechanism of trip hammers; it is presumed that every engineering apprentice has seen trip hammers, or can do so, and the plan here is to deal with what he can not see, and to learn by casual observation.

One of the peculiarities of trip hammers as machines is the difficulty of connecting them with the driving power,—especially in cases where there are a number of hammers to be driven from one shaft.

The sudden resistance offered to the shafts in starting, the irregular motion that is necessary in most kinds of forging, and the varying amount of power consumed, tend to destroy any connection between the hammer and the driving power. Rigid connections or metal attachments are inadmissible and slipping belts arranged so as to have the tension varied at will, is the usual and almost the only means of transmitting power to hammers that has been successful.

The sudden and varied resistance to line shafts that drive trip hammers tends to loosen couplings, destroy gearing, and produce strains that are unknown in other cases. Shafting arranged with the usual proportions for transmitting power will soon fail if applied to driving trip hammers.

The motion of trip hammers is a curious problem; a head and die weighing, together with the irons for attaching them, one hundred pounds, will make with a helve eight feet long from two to three hundred blows a minute. This motion exceeds anything that could be attained by a direct reciprocal motion given to the hammer head by a crank and far exceeds any rate of speed that would be assumed from theoretical inferences. The hammer-helve being of wood is elastic and acts like a vibrating spring, its vibrations keeping in unison with the speed of the tripping points. The whole machine in fact must be constructed upon the principle of elasticity throughout and in this regard stands as an exception to almost every other machine known. The framing for supporting the trunnions, which a person without experience would suppose should be made with great rigidity, is found to answer best when composed of timber, and still better when this timber is laid up in a manner that allows it to spring and yield.

Starting from the dies and following through the details of a trip hammer to the driving power, the apprentice will note how many parts contribute to this principle of elasticity: First—the wooden helve, both in front of and behind the trunnion; Next—the trunnion bar which is usually a flat section mounted on pivot points; Third—the elasticity of the framing called the 'husk,' and finally the frictional belt. This gives an idea of the elasticity that is needed in connecting the hammer head with the driving power, a matter that should be borne in mind as it will be again referred to.

Another peculiar feature in trip hammers is the rapidity with which crystallization takes place in the attachments for holding the die blocks to the helves, where no elastic medium can be interposed to break the concussion of the dies; bolts to pass through the helve, although made from the most fibrous Swedish iron, will not last on an average for more than ten days use, and often break in a single day. The safest mode of attaching the die block, and the one most common, is to forge it solid with a band to surround the end of the helve.

At the risk of laying down a proposition not warranted by science, I will mention, in connection with this matter of crystallization, that metal when disposed in the form of a ring, seems to evade the influences that produce crystalline change. A hand hammer for example, may be worn away and remain fibrous, the links of chains and the tires of wagon wheels do not become crystallized, even the tires on locomotive wheels seem to withstand this influence, although the conditions of their use are such as to promote crystallization.

The purpose of introducing the matter here is to direct the attention of the reader to the subject; his own experience can be used in confirming or condemning the accepted theories of crystallization.

Among the exceptions to the ordinary plans of constructing trip-hammers, the most noted perhaps, are those used in the American Armory, at Springfield, U. S., where small hammers with rigid frames and helves, the latter thirty inches long, forged from Lowmoor-iron, are run at a speed of "six hundred blows a minute;" as an example however they prove the necessity for elasticity, in the fact, that the helves and other parts have to be often renewed although the duty performed is of a light character.

CRANK HAMMERS.

Power hammers operated by crank motion, adapted to the lighter kinds of work, are now commonly met with in the forging shops of Engineering establishments. They are usually of very simple construction, and I will mention only two points in regard to such hammers, that might be overlooked by the apprentice in examining them.

First. The faces of the dies remain parallel, no matter how large the piece may be that is operated upon, while with a trip hammer, the top die moves in an arc described from the trunnions of the helve, and the faces of the dies can only be parallel when in one position, or when operating on pieces of a certain depth. This feature of parallel movement in the dies of crank hammers, is of great importance on some kinds of work, and especially so for machine forgings where the size of the work is continually varied.

The second matter to be noticed in hammers of this class, is the nature of the connection with the driving power, when there will, in all cases, be found the equivalent of the elastic helve, either air cylinders, deflecting springs or other yielding attachments, interposed between the crank and the hammer head, and generally the slipping frictional belt or frictional clutches, as in the case of trip hammers.

The apprentice will no doubt see various modifications of power hammers, constructed upon different plans, but all operating upon the same general principles, and easily analyzed and understood if the principle of their action is studied.

STEAM HAMMERS.

The direct application of steam to forging-hammers, is beyond question the greatest improvement that has ever been made in forging machinery; not only has it simplified the operations that were carried on before this invention, but it has added many branches and extended the art of forging, to purposes that could never have been attained except by the steam hammer.

The general principles of hammers that have already in part been explained, apply to hammers operated by direct steam, and the apprentice in forming a conception of steam hammers, must not fall into the common error of regarding them as distinct machines, or as operating upon new principles. A steam hammer is nothing more than the common hammer driven by a new medium, a hammer that receives power through the medium of steam instead of by belts, shafts and cranks. The steam hammer supplies other purposes besides transmitting power, and seems to be so perfectly adapted to fill the different conditions of power-hammering, that there seems nothing left to be desired.

Keeping in view what has been said about elastic connections for transmitting motion and power, and elastic cushioning of the vibratory or reciprocating parts, it may be seen that steam as a driving medium for hammers, fills the following conditions:

First.—The power is connected to the hammer by means of the least possible mechanism, consisting only of a cylinder, a piston, and slide valve, induction pipe and throttle valve; these few details taking the place of a steam engine, shafts, belts, tension pulleys, cranks and springs, with pulleys, gearing, and all details that are required between the hammer-head and the steam boiler in other cases.

Second.—The steam establishes the greatest possible elasticity in the connection between the hammer and power, and at the same time cushions the blow at both the top and bottom of the stroke, or on the top only, as the case may require.

Third.—Each blow given is an independent operation, and can be repeated at will, while in other hammers such changes can only be made throughout a series of blows by gradually increasing or diminishing their force.

Fourth.—There is no direct connection between the moving parts of the hammer and the framing, except the lateral guides for the hammer-head; the steam being interposed as a cushion in the line of motion, which reduces the required strength and height of the framing to a minimum, and avoids positive strain and concussion.

Fifth.—The range and power of the blows as well as their time, are controlled at will; this is the greatest distinction between steam and other hammers, and the particular advantage that has led to their extended use.

Sixth.—The power is transmitted to the hammers through a small pipe, that may be carried in any direction and for almost any distance at a very small expense, so that the hammers may be placed in such positions as will best accommodate the work, without reference to shafts or other machinery.

Seventh.—There is no waste of power by slipping belts or other frictional contrivances to graduate motion, and finally there is no machinery to be kept in motion when the hammer is not at work.

Keeping these various points in mind, the apprentice will derive both pleasure and advantage from tracing their application in steam hammers that may come under his notice, and the various modifications of the mechanism will only render investigation more interesting.

One thing more must be noticed, a matter of some intricacy, but without which, all that has been explained would fail to give a proper idea of steam hammer action. The valve motions are alluded to.

Steam hammers are divided into two classes, one class having the valves moved by hand, and the other, automatic valve movement.

The action of the automatic hammers are again divided into what is termed the elastic blow, and the dead blow.

In working with elastic blows the steam piston is cushioned at both the up and down stroke, and the action of the hammer corresponds to that of a helve trip hammer; the steam filling the office of a vibrating spring; the hammer gives a quick rebounding blow, the momentum being only in part spent upon the work, and partly arrested by the cushioning of the steam in the bottom of the cylinder under the piston. [To be continued.]

Immense Standard Pressure Gauge.—The Government is erecting a standard pressure gauge at the Smithsonian Institution at Washington for the purpose of testing gauges to be used in the experiments on steam boilers. It will have a one inch column of mercury one hundred and fifty feet high, and it will be possible by it to test accurately gauges to a pressure of 800 pounds per square inch.

Chemistry, Physics, Technology, etc.

THE EXTERNAL ASPECTS OF THE SUN—ITS PHOTOSPHERE AND SPOTS—ITS CHROMOSPHERE AND CORONA.

By PROFESSOR S. P. LANGLEY.

[Continued from vol. lxviii, p. 134.]

How hot is the Sun's surface? It has been estimated at almost every temperature. Sir John Herschel, Father Secchi, and others, place it at, *at least*, 10,000,000 degrees Fahrenheit,* others far less; the most probable estimate I think being that of Sir William Thomson, who considers it to be something near 30 or 40 times as hot as one of our blast furnaces. Whatever it may be, there, literally, the elements melt with fervent heat. Our blast furnaces vaporize a small portion of the iron they render, and the aggregate amount of iron which annually passes out of Pittsburgh chimneys in this condition is reckoned to exceed 5,000 tons. This seems a startlingly large amount, perhaps, but what is it compared with that of that great furnace, the Sun, whose fire-grate area is reckoned not in yards, but in square miles, of which its surface includes 2,300,000,000,000.

In the case of a furnace of known size giving a known amount of heat to each square yard of grate, it is quite possible to calculate accurately how long a given quantity of coal will last. Comparing the Sun to such a furnace, we find we know accurately the area, and adopting a probable value for the rate of emission, it becomes a simple problem in practical engineering to determine how long a given quantity of coal would last if delivered and burned at its surface at a rate of combustion which would just maintain this known heat.

Since the great numbers I have quoted convey by themselves no distinct idea, I have, in the way of illustration, computed how long the entire coal fields of Pennsylvania would keep up the actual solar heat, using the lowest probable estimate of the heat, and the highest estimate of the amount of coal we have under our soil. Let us suppose the actual source of the Sun's heat (whatever that is) to be withdrawn, and that to supply its place we could deliver all the coal which underlies the State, at the solar surface, and burn it with an oxygen blast, so that the Sun should radiate just the heat it does now. When

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* Since this lecture was delivered, Father Secchi has published the results of a comparison of the heat of the carbon-points in the electric-lamp, with that of the Sun, giving the latter a very much lower temperature than in his former estimate.

I finished the computation I thought I had perhaps made a mistake, and possibly you may think so, too, but I revised my figures and found them correct. Demonstrably the Pennsylvania coal fields would not last more than a very minute fraction of a second! I must return once more to this subject of the solar heat, but before I do so I wish to speak, though briefly, of the Chromosphere or the red envelope (commonly invisible to the telescope) with the flames which rise from it, and of the Corona.

THE PROTUBERANCES.

Few indeed, have seen these with the naked eye, as we ordinarily have to travel long distances to enjoy a brief direct sight of them from the track of a total Solar Eclipse. It has been my privilege to thus witness them on two occasions. Nothing can be more impressive than when to the spectacle of the Sun turned to darkness in a cloudless sky is added the sight of these red flames rising around its disc to the height of perhaps 50,000 miles. The spectacle is as brief as it is beautiful, the Government Eclipse Expedition having crossed the ocean in 1870 for an opportunity of observation which it was known in advance would last but two minutes. To all the other elements of grandeur in that scene was added that of the approach of the moon's shadow on the earth. We do not customarily reflect that the moon, which we ordinarily consider in its poetical aspect as it seems slow wandering among the stars—

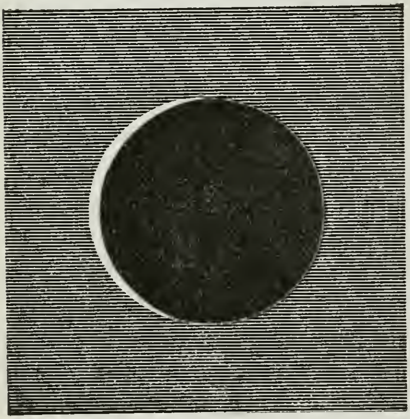

Fig. 3. The Sun just before Totality.

> "Like one who hath been led astray
> Through the heavens' wide, pathless way,"—

is, in fact, an immense projectile hurled through space at the rate of two thousand miles an hour. We do, however, realize this fact when its shadow is thrown upon the ground beside us, and sweeps across the fields where we are, and I think poetry need be no loser by exchanging its fiction for such a reality. On our right, that day, as we faced the fast disappearing Sun at Jeres, lay houses, vineyards, and orange groves; on our left, stretched the far-extended Andalusian plains to a distant range of lofty mountains called the Sierra Morena.

The moon's shadow suddenly appeared in the west, concealing the white house tops and darkening everything like the coming of sudden night, rushed over us and passed us with a speed greater than that of a cannon ball, and, almost instantly blotting out the distant Sierra Morena, seemed to have made but one leap from horizon to horizon. Only when the last ray of light was flitting, the red flames and Corona came out. Fig. 4.

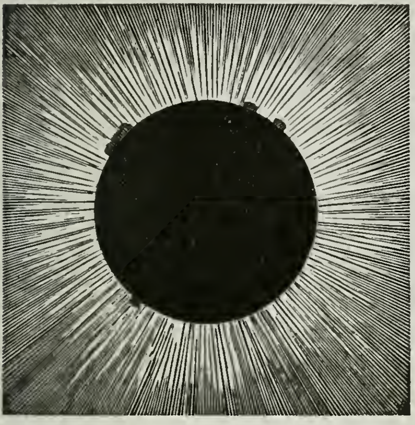

Fig. 4. Eclipse at Totality showing Corona.

I try to simulate the progress of the eclipse by causing a shadow to advance over the screen while moving a plate with my hand, but the halting motion conveys nothing of the impression which reality does when we see the regular and measured advance of the dark body of the moon, extinguishing the light till the last ray is gone—and the Corona appears.

It is impossible to enter on the great subject of spectrum analysis in explaining just how, without an eclipse, the spectroscope enables us to see the protuberances, and this is the less needed as so many here had the advantage of hearing the elucidation of this subject by Professor Barker, in this place. It does so, and so well that on the day before the 1870 eclipse I saw them as clearly through Professor Young's spectroscope, as at the moment of totality. But without intending to speak of the spectroscope further, I may show you a most recent and remarkable improvement in what are known as diffraction spectra, due to Mr. Rutherford, in the shape of these little pieces of glass and speculum metal which I hold in my hand, either of which is equal to a powerful train of prisms.

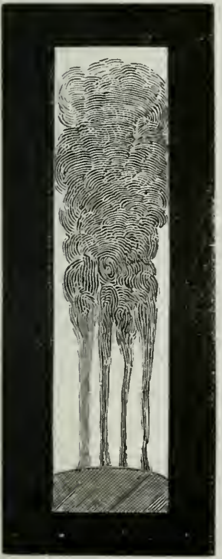

Fig. 5. Eruption from the Chromosphere.

When with it or the prisms we view the chromosphere, we appear to look through an extremely tall, narrow window, beyond which appears the limb of the Sun with the red chromosphere, and, if we happened to be looking at the part of the edge where an eruption was in progress, we might witness with it the rising of the rosy flame-clouds which are its products. Fig. 5.

We are supposed to witness in the red clouds you see rising, one of those tremendous eruptions of hydrogen vapor to which the protuberances of the chromosphere are largely due, and as it is important to see that gas can be luminous without burning, I call your attention again to this little illustration of the Sun where the protuberances which now appear are formed of real hydrogen behind the screen. As a fuller illustration of this important point, notice these glass tubes, called Geissler tubes, and which are filled with various colorless gases. When I pass the current from this Ruhmkorff coil through them, they glow with a mild light of various colors and would continue to do so for almost any length of time without waste.

These illustrations may help us to see that the light and heat I have described are not necessarily due to anything "burning up" as in the case of an ordinary fire, or as in the case of this magnesium wire which I light, and which does burn up like a candle.

Magnesium is found very plentifully in the Sun and so are other metals which do not burn so easily but which may all be vaporized by sufficient heat so as to form the metallic clouds I have described. While I prepare to try them in the electric lamp let me direct your attention to this screen, painted, in part, with Thallene, a remarkable substance extracted from the refuse of our Pittsburgh oil stills by Professor Morton, of the Stevens Institute, Hoboken, (and I cannot mention his name without adding that I owe to his kindness not only this illustration, but many other adjuncts to the present lecture). I have alluded to the heat which comes from the Sun, which we all feel and to its light which we all see, but you know there are yet the invisible rays which are commonly supposed (perhaps erroneously,) chiefly to induce chemical action. Thallene has the property of making visible these invisible rays. I light up the screen with the lime light and you see a little difference between one star and another. I throw on the upper rays of the spectrum, from this electric lamp, and the Thallene, by the action called Fluorescence, takes hold of the invisible rays which went across from the lamp and sends them back to us visible in the peculiar greenish light from every alternate star that is painted with it. I return from what is scarcely a digression to show you upon the screen the dazzling image of the carbon points, between which is now playing the intense light and heat of the electric lamp. I now turn out the light and place a piece of iron on a carbon point hollowed into a minute cup.

You see the inverted image of the carbon, with the iron resting on it, apparently upside down, owing to the action of the lens. I bring the points together, the electric flame leaps out again and there you see the image of the boiling iron on the screen. The changed light comes from it. I turn the iron out and put in a piece of pure silver, and the light which you see now comes from that metal as it burns; and, finally, I turn the lamp toward you and put a piece of gold upon the carbon. Splendor which fills our eyes comes from that burning gold, which is already molten and passing away into vapor. I use these illustrations solely in connection with the subject of the metallic vapors to which the photospheric forms are chiefly due; for it is only of the external appearance of the Sun that I have been speaking to-night, and I have tried to read but one chapter in the great volume of our knowledge, leaving the rest of the book unread. But beyond all else, we should find the further study of the Sun interesting in the fact of our personal relations to it. According to a familiar anecdote, George Stephenson, in days preceding those of the present knowledge of such facts, discovered for himself that it was the force of the Sun locked up in the coal, which really drove his engine, and we must remember that this is not only true, but that as regards ourselves, the statement that our own strength comes from the Sun, and that we cannot move except by the force it supplies, is something more than a figure of speech.

Helmholtz and others have shown that we, ourselves, are—physically speaking—exquisite ingenious machines for developing sun-power. All that grows and lives shares this dependence with us. The cars that may have brought us here were drawn by it; the wood of the floor on which our feet rest, was grown by it; the silk we may be wearing was spun by it—its agency was taken as the medium through which were formed the lips that now speak, and the ears that now hear. These are facts—not fictions, not even figurative expressions; but we must still distinguish between what is fact and what is speculation. Science may represent to us—and truly—that it knows nothing of man, but as a combination of certain elements, acted on by certain forces—elements which existed before him from the infinite remoteness of years, before the Sun himself began to shine. Science may say, and truly, that it knows nothing of man's relation to the Sun, which are not those of a thing formed to that which formed it. But while we shall do well to learn from it to make candid confession of ignorance, where ignorance exists, we shall err if we think her ignorance can ever really be our knowledge; and as we stand for a moment near the boundaries of man's thought, where science has led us only to let go our hand, if it be permitted to express anything which may be only personal, I will do so—not in the words of Helmholtz or Tyndall, but in those coming from another age of thought and adopt, as an expression of my own feeling, the words of Sir Thomas Browne:

"There is surely a piece of Divinity in us—something that was before the elements, and owes no homage to the Sun."

RESEARCHES ON THE TEXTURE OF IRON.

By M. Janoyer, C. E., Metallurgist.

(Translated from the *Annales des Mines*, Vol. 5, p. 90, 1874.)
(Continued from Vol. lxviii, p. 139.)

But the converse of the proposition is equally true; that is to say, having given a fibrous iron, it is sufficient to carry it to a high temperature capable of developing its weldability, in order to transform it into a granular iron. Indeed, by bringing one end of a bar of fibrous iron to a welding heat, a granular structure may be developed there; so that in this way we may produce a bar of iron fibrous at one end and granular at the other. This simple experiment, of the highest scientific interest as well as of the widest practical application, gives us the means of producing at will, either granular or fibrous iron according to the needs of the consumer; and this too, without any change in the material at first employed.

In the preceding statements we find an explanation of the reason why railway companies require that their iron rails should be made of granular iron; and why contractors for machinery demand granular iron for those pieces which sustain friction, and which therefore must take a good polish. The reason is that granular iron, being thoroughly welded, is sure not to laminate under the weight of the locomotive or by the friction of rubbing surfaces; as would be the case with fibrous or imperfectly welded iron.

What has now been said applies to the production of crude iron or merchant bar; and it may be asked what becomes of this crude granular or fibrous iron when it is submitted to refining. I answer all the phenomena are reproduced and in precisely the same manner.

If two or more bars of crude granular iron be superposed so as to form a fagot, and this fagot be heated to a welding heat and passed through the series of grooves necessary to form it into a bar, the result is always granular iron; provided, that, on issuing from the last groove the temperature of the mass is sufficiently high to ensure complete welding. But if, on the other hand, the bar issues from the last groove at a simple red heat, the texture will be fibrous, simply because it is not welded. Rolled too cold, the metal is disintegrated, and the welding destroyed; the particles slide over each other, they are elongated and consequently a fibrous texture is the result.

As a proof of this sliding, a notch is made upon the side of the fagoted bar, half an inch in depth and perpendicular to the end of the bar. The fagot, heated to a welding heat, is then passed through the necessary series of grooves, the notch still remaining normal to the bar. But at the instant when the temperature is no longer sufficiant to maintain the pasty state necessary for welding, the notch changes its form and becomes as it is worked, more and more the shape of a horizontal <.

This simple experiment obviously proves that in the groove, the center or heart of the bar, receives, in passing, only a vertical pressure, and that the two surfaces slide upon it, producing exactly the observed elongation. The proof of this sliding is seen at once on glancing at the bars as they issue from the rolls, and before they are passed to the shears. The center of the extremity which comes through first, always projects beyond both the superior and inferior portions. The reverse is the case with the other end of the bar.

At the moment when the bar, heated to a dull red heat, takes in the groove, the cylindrical surfaces present an obstacle to the passage of the metal, only the center of which passes easily, while the upper and lower portions are obliged to recede before the cylinders which slide upon the bar. If this bar retains at the last groove, a sufficiently high temperature so that there may be no sliding and consequent disintegration of the mass, and so that the welding actually takes place, the bar will be granular in texture. This condition of things is well seen in large bars, which, during the entire process of rolling, have preserved a sufficiently high temperature.

It happens sometimes, however, that in these large bars of granular iron, fibrous iron may be discovered at certain points. The experienced eye at once recognizes the fact that this fibrous texture is only to be found at the junction of the bars which make up the fagot. This fibrous iron, therefore, is due only to the interposition of cinder, a foreign body which prevents the welding. For this reason, many forge masters, in order to ensure the expulsion of this cinder, frequently subject the fagot to the steam-hammer before rolling it; thus ensuring the removal of the interposed oxides, and securing a perfect weld.

If we cast our eyes over the series of machines employed in the refining of iron, we shall notice that the common practice, after many unfruitful experiments, has returned uniformly to the hammer, under forms more or less various, and has abandoned the squeezer, the rotary shingling machine, and all those other appliances, both simple and ingenious, for effecting a rapid but at the same time a defective shingling. Heavy hammers have alone given uniformly good results.

I mentioned above that hammering in the cold gives to fibrous iron brilliant plane facets, not belonging to the grain inherent in the metal itself. I will attempt now to give my understanding of the manner in which this transformation of fibrous iron in the cold, into granular iron, operates, being produced, as it is, by blows and by successive oft repeated vibrations.

An examination of the wheel tyres of carriages which have run upon a pavement, leaves no doubt of the actual fact. Generally, these tyres are made of fibrous iron. After a period of use more or less great, the iron is found to exhibit large brilliant plane facets. An explanation of this result is easily arrived at by considering what takes place when, by means of a hammer of a certain weight, a bar of iron is struck at any point of its length. The portion immediately between the hammer and the anvil is displaced laterally and is obliged to overcome the resistance of those portions of the bar lying beyond the immediate action of the hammer. The resistance of the two ends acts precisely like two other hammers, and tends to compress the bar in the direction of its length. Hence there is compression of the mass, and hence the grain observed, which always appears, when thus produced, in the form of large brilliant plane facets, entirely distinct from the fine grain originally present in the iron. Precisely the same facets are to be seen on the half section of a bar of fibrous iron which has bent before breaking. The facets are developed by the longitudinal compression of the fibers.

PROOFS DRAWN FROM THE STUDY OF THE STRUCTURE OF IRON UNDER THE MICROSCOPE.

From what has now been said, it appears that from a thorough examination into, and a careful comparison of the different modes of manufacturing iron, the result is reached that this metal in a state of purity and homogeneity, resulting from a good method of fabrication, where the conditions of temperature have been properly observed, is always granular; and, moreover, that this granular texture becomes fibrous whenever the temperature during the process of working, has been allowed to fall so low that a thorough welding of the entire mass cannot take place.

If this be so, the study of iron under the microscope must necessarily reveal a perfect compactness of the metal when in the granular condition, and a corresponding want of homogeneity in the iron when fibrous. This prevision is completely verified by experiment.

This result, however, important as it is, is not the only one obtained by the use of the microscope.* As we shall see further on, this instrument discloses to us in the case of non-welded, that is to say, of fibrous iron made in the puddling furnace, the presence in it of black pulverulent matter (slag) such as I have already mentioned when speaking of the manufacture of iron by the English process. This black substance is closely lodged in the spaces between the fibers, spaces distinctly visible under the microscope.

The study of iron with a Coddington lens for example, magnifying about thirty diameters, has enabled me to establish clearly and incontestably the following facts :—

That iron in a state of purity, is granular.

That granular iron is compact and thoroughly welded.

That fibrous iron is porous, and not perfectly welded.

That mixed granular and fibrous iron is not uniformly welded throughout its mass.

That coke iron (English method) contains foreign matters between its fibers.

That coke iron presents ordinarily a fibrous texture and a structure but slightly homogeneous owing to defective welding.

Let me now give in detail, the observations which have led me to these conclusions. A specimen of iron, made with great care from the best quality of charcoal pig, and therefore being as pure as it is possible to obtain the metal in the present state of the metallurgical art, exhibited, when its fracture was closely examined with the naked eye, a very fine granular structure, showing only a few trifling torn fibers. The finger readily detected upon this surface, the asperities which have given the name "apiform" to this iron. This name, however, as we shall see, is entirely an improper one, since the fibers have not in fact the crooked form of a fish-hook.

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*If any one should desire to repeat and to extend these observations upon iron, they can use, in place of a microscope which is costly and cumbrous to manipulate, simple magnifying glasses of high power, magnifying at least 30 diameters. A lens of this power is quite sufficient.

Submitted to examination with the lens, this fractured surface shows a mass of plane facets, entangled in each other without apparent order. At the moment of rupture, certain particles, situated in the plane of fracture and parallel to the acting force, are separated, or in some sense, torn apart from each other, and therefore give, under these particular conditions, flat grains showing brilliant facets. Other particles, on the contrary, being in planes more or less inclined to the direction of the acting force, present themselves to the eye when separated, at a greater or less angle, and produce, as a whole, a texture very fine grained in appearance. In the latter case, the iron has always a greater tenacity, because the particles of the metal, caught between the planes, and crossing in all directions, being more or less inclined to the acting force, are obliged to produce considerable laceration in order to separate from each other. We see, therefore, independently of the granular texture inherent in pure iron, that, of two irons, the one which has the finer texture offers the greater resistance to strain.

Another deduction, not less important (and one which will tend to rectify some very wide-spread errors, too) is that the fineness of grain, taken in absolute sense, is not always due to a more considerable amount of carbon, and consequently, does not always argue a steely tendency. Fineness of grain is a fact entirely independent of carbon. It is sufficient on this point, to call attention to Swedish iron, which, although very steel-like, is not unfrequently very coarsely granular. My own view is, as already stated above, that this fineness of grain only argues an iron of superior quality with reference to its tenacity.

Moreover, in pure iron, speaking metallurgically, independently of its granular texture, the magnifier reveals a compactness and a perfect homogeneity which can arise only from a complete welding.

If, now, a specimen of fibrous iron be submitted to microscopic examination, the results are entirely different. Aside from the very apparent lacerations of fiber, its more or less brilliant aspect, and its greater or less elongation before rupture, the experienced eye is not slow in discovering in it a want of homogeneity which is never shown in granular iron. This want of homogeneity becomes much more striking when the fibrous iron is examined with a powerful magnifier. There is then to be seen, even in the metallic mass itself, numerous holes and cavities all elongated in the direction of the axis of the bar. These holes are of all forms and of all dimensions. The fractured surface is literally perforated with them; so much so, indeed, that it presents almost the porous aspect of a reed. Perhaps the comparison would be more accurate if we should say that the appearance presented is like that exhibited by a section of a sponge.

Since these cavities keep the different particles of the mass at a distance from each other, and oppose an obstacle to that intimate union of them which constitutes welding, we may even now assert that the microscope establishes the fact of imperfect welding in fibrous iron. Worked, as this iron has been, at too low a temperature, the juxtaposed particles of metal have slid over each other, producing laceration and consequently, the cavities which are observed. It may even happen that a mass of iron which at the outset is thoroughly welded, may become unwelded again by working it at too low a temperature. The result, however, so far as the structure is concerned, is, in both cases, the same.

Iron containing both granular and fibrous metal mixed, can no longer be considered a badly refined iron as Karsten affirms it is; such an iron is simply a metal imperfectly welded.

Beside the influence of the temperature which prevails at the time of working the iron, there is still another and purely mechanical cause which influences its texture. This is the introduction into the metal of some foreign substance, such as unmelted sand, basic slag, etc., which prevents the contact of the molecules. In most cases it is basic slag; and this, being enclosed within the mass, and being but incompletely expelled therefrom, prevents a perfect welding and causes the fibrous structure. In proof of this we see the masters of experimental forges order their workmen to throw highly siliceous sand upon the iron when at a welding heat, in order to favor the expulsion of foreign matters by forming less basic slags, and in this way, to favor the production of a more perfect weld. This slag, so injurious if not removed, is, it seems to me, one of the principal causes which differentiate (the quality of the cast iron being equally good in each case) between charcoal and coke iron. It prevents perfect welding in the case of the latter, and gives to the fiber a dark appearance. Moreover, an examination of the iron with the microscope leaves no doubt upon this question. Fibrous charcoal iron, in which no black places are discernible with the magnifier, has always a brilliant silvery appearance, and never presents the dull, black, and short fiber characteristic of coke iron.

In order to give an accurate idea of the injurious influence of slag thus interposed throughout the mass of the iron, I will mention here an experiment which seems to be entirely conclusive. It is well known that in the manufacture of charcoal iron by the Franche-Comte method, there is left, at the close of each refining operation, exactly under the opening of the tuyere, a certain quantity of iron (about two kilograms) from the preceding heat; the object being to favor the production of basic slags, the reaction of which upon the foreign metals and the carbon of the pig, is much more energetic than that of neutral slags. (This, in fact, is the scientific explanation of the assertion of the forge-masters, that this iron in burning, gives heat to the slag.) In 1859–60, in order to increase the production of charcoal iron, I ordered about fifteen kilograms of scrap-iron to be added to each charge, believing that it would be thoroughly incorporated with the iron produced from the pig. My surprise was great when, on weighing the product, it was found that the loss in refining was the same which had occurred in previous operations before the addition of the scrap; and that the iron, designed to be drawn into wire, was of a very poor quality. The explanation, however, is simple. The scrap-iron, added too soon, had been entirely oxidized and had formed a highly basic slag, which was not subsequently expelled from the mass. On attempting to draw the iron into wire, this foreign substance abraded seriously the draw-plate and the wire produced broke into short pieces. Returning again to the old method and refining the same pig without the addition of scrap-iron, the quality of the iron became excellent. The experiment was to me, a significant one.

It appears then that the observations which have been made upon iron by means of the microscope, lead to exactly the same conclusions as those obtained by a comparison of the different modes of manufacture of this metal.

INTIMATE RELATION BETWEEN THE PHYSICAL PROPERTIES OF IRON AND THE WELDED CONDITION OF THE MASS.

Density.

Granular iron being more thoroughly welded than fibrous iron, and consequently more compact and more homogeneous, we should naturally conclude *a priori*, that fibrous iron must have a specific gravity below that of granular iron. This supposition is verified by everything that either theory or practice has to offer upon the question. The learned Upsal professor, Hassenfratz, gives as the density of thoroughly welded granular iron 7·791; and of soft fibrous iron 7·751. Flachat, Barrault, and Petiet give for the former kind of iron, a density of 7·780 and for the latter, of 7·600; a much more considerable difference. In actual practice, we notice that those ironworks which make rails of fibrous iron, can only obtain the required weight per running meter by giving a greater thickness to the transverse section; while those works which produce a granular iron, attain very easily the required weight by following exactly and almost mathematically, the pattern rail furnished by the railway companies. I might cite many other examples upon this point, all proving the greater density of granular iron. But the fact appears to me already demonstrated.

Hardness.

The best iron, says Karsten, is that which possesses the greatest hardness; and he places in the front rank as to quality, the very hard iron which is always granular, very pure, and has a silvery fracture. This iron is the type of a thorougly welded metal; it does not contain any slag distributed throughout its mass, nor can any solution of continuity be observed in its texture.

Tenacity.

The tenacity of iron is the resistance which the metal opposes to an external force which tends to separate the portions composing its mass. According to the mode of action of the force, we may have:

Resistance to traction.

Resistance to compression.

Resistance to flexure.

Granular iron resists better than any other, both traction and compression. This should necessarily be the case, since it is perfectly welded throughout its mass; and hence the surfaces to be separated are more considerable than those of fibrous iron of equal section.

As to resistance to flexure, however, the reverse is true. Fibrous iron is not welded; an intermolecular approximation is consequently possible before the point of rupture of the bar is reached. This kind of iron, therefore, opposes a greater resistance to flexure than granular iron, but it has much less elasticity.

Malleability.

Malleability is the property in virtue of which iron is extended under the hammer. This property is especially developed in soft irons, which are irons not welded and always fibrous. Very hard iron, on the other hand, that is to say, welded or granular iron, is hammered out less easily.

Ductility.

This is the property which iron possesses, of being drawn into more or less fine wire without breaking. What is necessary in order that an iron may be ductile? Two conditions: homogeneity, that it may pass the wire-plate, and tenacity, that it may support the traction. Very hard iron, that is to say, our granular welded iron, is the only kind suitable for this purpose. Fibrous, non-welded iron possesses but little homogeneity and could not pass the draw plate; moreover, it would break very often. We see, therefore, that in practice, granular iron is sought after for this purpose and that fibrous, or non-welded iron is rejected. Karsten tells us:* Neutral iron, whatever be its hardness, can be drawn into very fine wire." The granular neutral iron of this siderurgist is evidently our welded iron. If we generalize our observations, we shall notice that those iron-works which make granular iron, i.e., a thoroughly welded and homogeneous iron, obtain a product much more beautiful and free from cracks than that obtained by those establishments which make fibrous iron.

In conclusion, we see again that all the physical properties of iron coincide readily with the view which we have adopted, taken from the standpoint of its texture.

INFLUENCE OF CERTAIN METALLOIDS UPON THE TEXTURE OF IRON.

Sulphur.

If we glance at what has been written concerning irons containing sulphur and which are consequently hot-short or red-short, we shall find that these irons have generally a fibrous structure, are more or less dark in color, have short fibers, show an absence more or less complete of weldability and, in the cold, offer great resistance to rupture by flexure. In this short statement an entire confirmation of my

* *Manual of Metallurgy*, i. 86.

position is contained. The absence of weldability given by the sulphur, must necessarily produce a fibrous structure. The fibers are black and short because of the diffusion of slag throughout the mass. These irons offer in the cold, great resistance to flexure because of the possible approximation of the molecules before the point of rupture is reached. All these characters belong to irons which are not thoroughly welded.

Phosphorus.

In speaking of the influence of phosphorus upon the structure of iron, I omit from consideration those compounds of phosphorus and iron in which the metalloid is present in sufficient quantity to form true phosphides, since these compounds do not affect the question which I am discussing in this memoir. I shall speak here only of irons containing very small quantities of phosphorus, into which this metalloid enters only in amounts of a few thousandths. Phosphorus under these conditions plays a part diametrically opposite to that of sulphur. Phosphoretted irons weld with facility. Karsten* and all practical metallurgists also tell us of the very considerable weldability of irons which contain phosphorus. Now, since these irons have always a granular structure, we see here additional proof that these granular irons are our thoroughly welded irons.

RÉSUMÉ.

Although it would be possible for me to bring forward still other proofs in support of my position, I will stop here, believing that I have sufficiently elucidated the question and have demonstrated that iron possesses only a single texture, and that the granular one; and that this texture depends on one of the most essential properties of iron, its weldability. Every other kind of structure in iron is only a change in the granular texture, resulting from imperfect welding during the process of working the mass.

NOTE UPON THE MEMOIR OF M. JANOYER.

By M. L. GRUNER.

It is by no means easy to observe the real texture of a more or less malleable metal. In breaking it, certain portions of the bar in which especially it is necessary to study the internal structure, are always deformed. Moreover, it is now certain that many of the metals if not all, take on a crystalline structure when subjected to prolonged cooling. The crystals too are larger and coarser, the larger the metallic mass in which they are formed. Hence the cavities with crystalline sides which are observed in large wrought iron forged shafts, when by accident, these are ruptured.

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* *Manual of Metallurgy*, i, § 196.

It follows from these facts, that the rupture of a bar of more or less malleable iron, enables us to judge of the appearance of the fracture may be, but not of the texture properly so called. What M. Janoyer says above of granular and of fibrous irons, therefore, applies in reality only to fracture, not to texture.

Fracture may be produced either by a sudden, sharp and violent blow, or by a gradual and slow bending. According to the mode of rupture, the appearance of the fractured surface will be very different. When the break is effected by a slow flexure, the fibers of the iron may stretch and elongate themselves before rupturing; a fibrous fracture would then be produced. While the same iron, suddenly broken, may present a more or less granular fracture. In order to compare fractures, it is very necessary to operate in precisely the same way in all cases and upon bars of the same dimensions. A gradual bending produces precisely the same tearing effect upon the iron as too cold rolling; the molecules slide over each other, on the convex side of the bend; there is tearing and consequently, a fibrous fracture.

These facts excepted, it is entirely certain that the observations presented by M. Janoyer, are, in great part, correct. It is undoubtedly to interposed slag, very often, that it is necessary to attribute the imperfect welding of certain irons, and their tendency then, to present a fibrous fracture. But it is necessary also to recall the fact that when a partially carbonized iron is submitted to a welding heat, the carbon, by reducing the basic slags, may entirely disappear; while an iron not carbonized, is not, under the same circumstances, modified in any way whatever. Hence it happens that highly carbonized irons are actually more ready to assume or to maintain a granular fracture, than irons feebly carbonized.

M. Janoyer also seems to me to criticise wrongly the assertion of Karsten "that an iron composed of fibers and grains mixed, is a badly refined iron." It is quite certain that a badly refined iron, containing silicon or even slag in some parts of it, will show precisely this faulty welding at those places and will show a fracture varying in character at its different points.

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EDITORIAL.

ITEMS AND NOVELTIES.

Sir William Fairbairn, F. R. S.—We take the following obituary notice of this celebrated English Engineer from the *Journal of the Society of Arts,* of which Society he was for thirty years an active member, and at one time Vice-President:

"Sir William Fairbairn died on Tuesday, the 18th day of August last, in his 83d year, at Farnham, Surrey. He was the son of Mr. Andrew Fairbairn of Smailholm. He was born at Kelso in Roxburghshire in the early part of the year 1789, and received his education as a boy at a small school at Mullochy, in Rosshire, subsequently acquiring his professional training at Newcastle-on-Tyne. He settled in Manchester in 1817, in partnership with Mr. Lillie, in conjunction with whom his name rose to become that of one of the leading firms among the machine makers of that city. Mr. Fairbairn acted in conjunction with Robert Stephenson in the planning and execution of the celebrated Britannia and Conway Tubular railway bridge across the Menai Straits. In 1850, he published in the Philosophical Transactions of the Royal Society his 'Experimental Inquiry into the strength of wrought iron plates and their riveted joints, as applied to shipbuilding and to vessels exposed to severe strains.' To him also we owe many useful researches into the causes of the explosions of steam boilers. He was a Fellow of the Royal Society, a corresponding member of the French Institute, an active or honorary member of almost every Society connected with engineering science in this country, and of many philosophical societies; and had received medals or other marks of recognition for his services to science from most of the crowned heads of Europe. He was one of Her Majesty's Commissioners for the Great Exhibition of 1851, and again took an active part in the organization of the second Great Exhibition in 1862, in the same capacity. He was also a member of the Jury of the Mechanical Department of the Great Exhibition of 1851, and acted as President of the Jury of the corresponding section of the Exhibition of Industry at Paris in 1855. In 1861, he occupied the position of President of the British Association for the advancement of Science. He was created a Baronet at the recommendation of Mr. Gladstone in 1869. The greater part of Sir William Fairbairn's acknowledged publications appeared in the Philosophical Transactions of the Royal Society, in the Reports of the British Association, and in the Transactions of the Philosophical Society of Manchester, in which he filled the chair of Dalton. Some of his works, however, were also published separately. Among his chief productions may be specified treatises on 'Canal Navigation,' on 'The Strength and other Properties of Hot and Cold Blast Iron,' on 'The Strength of Locomotive Boilers,' on 'The Strength of Iron at Different Temperatures,' on 'The Effect of Repeated Melting upon the Strength of Cast Iron,' on 'The Irons of Great Britain,' on 'The Strength of Iron Plates and Riveted Joints,' on 'The Application of Iron to Building purposes in general,' on 'Useful Information for Engineers,' etc."

Melting of the Metal for the New Metric Standards of the International Metric Commission at Paris.—At the meeting of the Executive Committee of the International Metric Commission in October last, the fusion of the large single ingot of platinum-iridium, weighing 250 kilograms, out of which all the new metric standards were to be constructed, was fixed for the end of the following April, but the completion of the operation was delayed by accidental circumstances until the middle of the following month. As this was the first occasion on which any attempt had ever been made to melt together more than a few kilograms of platinum or of platinum alloyed with iridium, it was necessary to make a great number of experimental meltings during the intermediate time in order to secure success in the great operation.

All the actual meltings of the platinum and iridium have been made at the Conservatoire des Arts et Metiers, in a building erected for the purpose. The work has been carried out under the superintendence of M. Tresca, the Sous-Directeur of the Conservatoire, who is also honorary secretary of the Commission, and more immediately intrusted with the technical operations of constructing the new standards. He has had the advantage of the cordial assistance of Mr. George Matthey, of the firm of Johnson and Matthey, Hatton Garden, from whom the large mass of platinum and iridium was obtained. Mr. G. Matthey has had large personal experience in melting platinum, and he remained at Paris from the beginning of April assisting in the work.

It was necessary that the whole of the platinum and iridium should be separately assayed and purified previously to their being melted together. This process was entrusted to M. Henri Sainte-Claire Deville, and carried out at the Ecole Normale, of which he is director. The greatest difficulty in the purification consisted in getting rid of the osmium, which is found in the natural ore in combination with platinum and with iridium. But the chemical difficulty was satisfactorily overcome by M. Deville after many experiments made by him.

The whole of the platinum and iridium had thus been ascertained to be perfectly pure when delivered to M. Tresca for melting. The first process was to melt portions of the pure platinum, its melting point being about 1,900° C., and considerably lower than that of iridium, which is about 2,400° C. Portions of the platinum were then remelted together with iridium, in the proportions fixed upon of 90 per cent. of platinum and 10 per cent. of iridium. Quantities of from 10 to 15 kilograms of platinum-iridium were, in the first instance, melted together. Several of these smaller ingots were then remelted into larger ingots of rather more than 80 kilograms each, and the final operation was to remelt three of these larger ingots into a single ingot of 250 kilograms.

Each of the meltings was made as nearly as possible of uniform form in a furnace heated with oxy-hydrogen gas. The furnace was made of a block of the ordinary sandy limestone used for buildings in Paris. For the smaller ingots a square block of stone was employed with a hemispherical cavity about 6 in. (15 centimeters) in diameter, for containing the metal. This small block had a cover of similar form, and through its middle was a vertical hole, about ¾ in. in diameter, in which the tube for conveying the gas was fixed with mortar. When the metal was placed in the furnace, and the jet of lighted gas directed upon it, sufficient mortar was placed on the joining of the upper and lower blocks of stone to make it air-tight. For the three larger ingots a long oblong furnace was used, with a cavity of the same breadth, but a little deeper and much longer, and three gas-tubes were used. The largest furnace required for the whole quantity of metal had six gas-tubes, each about one inch in diameter, inserted in the upper block. The ordinary illuminating gas was used, mixed with the requisite proportion of oxygen gas, made on the premises and stored in a large gasometer placed near the furnace-room. For obtaining a sufficient blast the power of a 15-horse steam-engine was employed.

In order to facilitate the melting, it was necessary first to divide the larger ingots into small pieces. About half the quantity for a single melting, thus divided into small lumps, was placed in the mould, and when this was completely melted the remainder, which had been drawn out into long thin bars, was introduced gradually through two small holes opposite each other in the furnace. These holes also enabled the interior of the furnace to be seen, together with the progress of the melting, and they could be closed by stone plugs when requisite. The division of the ingots was a difficult operation, as this alloy of platinum and iridium is harder than ordinary steel. A V cut, about ⅛ in. deep, was made around the ingot with a cold chisel, though not without splintering the edges of a considerable number of the best tempered chisels. The ingot was then placed under a hydraulic press, supported upon the rounded tops of two strong iron bars, a sufficient distance apart. The rounded part of a third bar was placed upon the ingot, in the line of the cut, and the power of the press being applied, the ingot was broken in half, presenting in every instance a regular crystallized grain.

The melted metal was not cast into a separate mould, but was allowed to cool in the furnace. During the melting a portion of the interior of the stone, to the depth of about half an inch, became calcined by the excessive heat and formed into lime in a powdery state, which floated on the surface of the melted metal. When the metal was sufficiently cool, the stone mould was broken and the ingot removed to a bath of hydrochloric acid, which dissolved every portion of lime or other foreign matter upon the surface of the ingot, but does not act upon platinum-iridium. The ingot was then left quite clean and pure.

The first of the larger ingots of 80 kilograms was successfully melted on April 25. The second was melted on May 1, when Marshal MacMahon, the President of the Republic, accompanied by M. Deseilligny, the Minister of Commerce, were present unofficially, and remained during the whole process, appearing to take great interest in the operations. The third of the larger ingots was melted on May 7.

The melting of the great ingot of 250 kilograms took place on May 13th, in presence of nearly every member of the French Section of the Commission, of M. Struve from St. Petersburg, MM. Stas and Heusschen from Brussels, M. Bosscha from Holland, Prof. Miller and Mr. Chisholm, delegates from Great Britain, and other foreign commissioners. It was successfully accomplished with the greatest facility and regularity, and without the slightest hitch or accident.

The dimensions of the cavity in the furnace, and consequently of the large ingots produced, were as follows:—

	Meter		Inch
Length	1·24,	or about	44·9
Breadth	0·15,	"	5·9
Depth	0·07,	"	2·8
Thickness of stone above the cavity	0·15	"	5·9

The time occupied in the process was as follows:—

2.10 P.M.—Furnace lighted and heated by degrees.
2.24 " —Furnace thoroughly heated.
3. 4 " —Contents of metal (130 kilograms) melted and bars begun to be introduced.
3.27 " —All the metal melted.
4.15 " —Metal entirely solid, but still at white heat; lid lifted.

In about half an hour the mould was broken and the ingot removed to the hydrochloric bath. When taken out it was examined, and found, to all appearances, perfect.

The stone used is so remarkably slow a conductor of heat, that when the whole mass of metal was in a melted state the upper surface of the stone was hardly warm, as was tested by the hands of several of the persons present being placed upon it.

Portions of the three large ingots had been previously tested and found to be very nearly indeed of pure platinum and pure iridium in the proportions of 9 to 1. The large ingot will also be assayed, and, if deemed necessary, again melted, in order that the requisite homogeneity may be attained.

The work of constructing all the new line-standard meters from this single ingot will at once be proceeded with, and there will be sufficient surplus metal for making first all the new standard kilograms, and then such number of end-standard meters as may be required.—*Nature*

Hydraulic Brakes.—We find in the *English Mechanic*, the following abstract of a paper upon the above subject, read by F. H. Varley and E. Furness, at the recent meeting of the British Association at Belfast:

In arresting a heavy body in motion, it is necessary to exert a force equal to the dynamic effect of the weight of the body, multiplied by the square of its velocity. Should this be effected instantaneously, a great concussion is the result, such being the effect experienced when a piece of machinery in rapid rotation is suddenly arrested by clogging, causing the teeth of the wheels to be stripped off, or the shafts broken or distorted, which frequently occurs with iron rolling mills, sugar-cane crushing mills, and not unfrequently causing the breaking of the screw shafts of steam vessels, and all classes of machinery subject to rapidly varying strains.

To reduce these enormous strains to within the working strength of the material of which the machinery is constructed, it is necessary to spread the force of the concussion over a portion of a revolution or revolutions, or period of time and so destroy its intensity. Contrivances for effecting this purpose, have hitherto taken the shape of friction brakes or clutches. They, however, are open to the objection that they consume a large amount of useful power by generating heat and destroying the surfaces by abrasion.

The authors describe a means of attaining a better result by hydraulic pressure, rendered elastic by placing in the fluid elastic substances, such pressure acting against the face of a ram working in a cylinder. To convert the longitudinal motion of the ram into the rotary motion of the shaft, they employ the following arrangement:—The wheel which communicates the power to the machinery is bored to fit freely on a shaft, and has a boss with its face on the inner side shaped of a spiral incline or screw form, and which is made to bear against an annular plunger, the outer end of which is shaped to the counterpart screw form. The hole in the plunger is bored to the same size as the wheel, and works in a cylinder fitted concentrically on the shaft which passes through the hole of the ram and wheel, the ram being made water-tight, by suitable packings, or leathers, both with the shaft and the cylinder. The outer end, or mouth of the cylinder has slots or recesses cut into it longitudinally, in which lugs or projections on the ram work, so that the ram can slide in and out the cylinder, but cannot turn without the cylinder turns with it. Proper inlets for charging the cylinder with fluid and elastic balls are provided.

If the shaft be revolving and the wheel driving the machine is stopped, the ram is immediately pressed into the cylinder and compresses the elastic material placed in the fluid by the spirally inclined faces rising one upon another. The wheel at the same time, is prevented from moving laterally along the shaft by a fixed collar on the outer side of the wheel; this motion of the ram allows the shaft to continue its rotation while the wheel is held by a sudden shock or stoppage, so that the machinery in such emergencies is gradually pulled up without being smashed to pieces. In crushing mills, through too heavy a feed, the rolls only require to be allowed to slacken in speed to admit of the cane yielding under the pressure, when the obstacle to rapid rotation has passed the rolls. The pressure stored up in the cylinder reacts on the ram, and by the spirally inclined end acting on the counter-form boss of the wheel, quickly brings the rolls to the speed of the driving shaft and thus utilizes the force of the strain.

The Artist's Rotary Color and Brush Stand.—At the meeting of the Institute held on Wednesday evening, September 16th, a stand was exhibited, invented by Mr. Samuel James, and for which a patent has been allowed. It will ultimately take the place of the old and inconvenient color box, as it enable the artist to have his colors, brushes, palette, oils, turpentine and other requisites at his side in a compact and convenient form; thus saving time and annoyance by keeping everything in such order that he can select at a glance from the stand, the color, brush, or whatever else he may wish to use. It is not only useful because of its complete arrangements, but it is also an ornamental object in the studio. The following description of the stand will show its adaptation to the purpose for which it was designed: Upon an ornamental cast iron tripod is affixed an upright wrought iron stem for supporting, 1st. The Palette holder which is triangular shaped and revolves upon the stem, being held at the proper height by a pin passing through the stem. 2d. A Rack divided into compartments for holding the tubes of colors, space being left above each compartment to allow the artist to mark each compartment with the color in the tube, thereby being enabled to select the color from the tints in the space. The upper part of this rack is arranged to hold bottles for oil, varnish, turpentine and wash cup; this rack also revolves upon the stem. 3d. Resting upon rack 2 and fitting around the stem is a water cup for keeping brushes soft that have not been washed free from paint, the brushes being held in the cup from the brush rack. 4th. A brush rack consisting of a wheel the outer edge of which has concavity sufficient to hold a spiral wire spring, which will adapt itself to hold brushes of any size. 5th. An ornamental cone-shaped top used as a brush receiver, into which the artist may drop his brushes after placing his palette upon its rack. J.

Editorial Correspondence.

[We have received from a gentleman of this city prominent as an Engineer, the following valuable letter upon the use of screw piles as foundations, written to him by Col. Ellers in response to a letter of inquiry. We are sure that the long experience of Col. Ellers in these matters gives to his words a weight of authority which will make the statements in his letter as acceptable to our readers as were his views on the use of nitro-glycerin, published in the September number of this Journal.—Ed.]

On the Use of Screw Piles as Foundations.

My Dear Sir: I fully concur with you as to the non-advisability of using screw piles, or, in fact, piles of any description, in the work in question, and I fail to comprehend how or in what manner their use can be defended either on the ground of durability or that of economy. With a solid rock bottom overlaid with a deposit of soft mud but 5 or 6 feet deep, and with only 6 or 8 feet of water at the site of the proposed work, I do not see wherein stability of structure can be secured or economy attained. Screw piles have been used by European engineers for many years, and that master of constructive art—Brunel—was, I think, the first to design and use a hollow cast iron cylindrical pile, with an exterior thread or spiral flange on the lower end, whose width varied from 12 to 30 inches, according to the size of the pile and the nature of the material into which it was set or screwed. Solid wrought iron screw piles on the "Mitchell" principle are extensively used abroad in the construction of piers, jetties, and foundation supports of almost every description, and, where uncontrolled by local circumstances, have proved alike, strong, durable and economical. I am not aware that the nature of the water has ever made any difference in their adoption by engineers. They have been used in the construction of one or two lighthouses in this country; and in Europe, Asia, and Australia, their use by English engineers has been quite extensive. Their diameter varies from 4 to 8 inches, and, while the latter dimension (the diameter) does not materially affect the cost of a cast cylindrical pile on the Brunel principle, it becomes a limiting item in the use of solid wrought iron piles, and to such an extent that a diameter much exceeding six inches is rarely used. The spirals or screws used on the Mitchell pile are always of cast iron, and their diameters—from out to out—vary from 2 to 4 feet. The resistance to settlement of a properly proportioned and well made screw pile in good sand or other material equally compact and reliable, and not subject to disturbing influences, is $5 D^2 = W$, wherein $D =$ the diameter of the screw, from out to out, in feet, and $W =$ the safe load in tons of 2240 lbs. Greater loads than those given by the above formula have been safely used, but experience teaches me that it is not always best to approach too near the dividing line between theory and practice. The setting or screwing process on shore or in water of ordinary depth is extremely simple and economical. A temporary platform, or a raft or float is securely moored at the site of the proposed work—the rigidly fixed platform on timber piles being the best, however, and its area or size is controlled by the number of piles to be driven or screwed, the position and application of the power for driving, and similar local circumstances rendered imperative by the location and character of the work. The iron piles are then accurately adjusted, and kept in place by a few temporary "guide timbers," a timber wheel from 10 to 20 feet in diameter is keyed or fitted to the upper portion of the pile, a rope is passed around the periphery of the wheel and carried to a crab winch, or any similar species of geared hand power conveniently located, and by means of which the wheel and pile are made to revolve, and the latter to enter the material in which it is to remain. Or, the pile may be fitted with an ordinary adjustable capstan head, and the requisite motion secured by hand or animal power in the usual manner in which capstans are worked. But little pressure or weight is required to make the pile enter its place and make its own headway thereafter. The length of a wrought iron pile is manifestly limited by its tensional resistance. the Mitchell pile readily passes through the most compact material, and will easily displace, in its descent, stones or boulders of moderate size. The spirals or threads generally pass but once, or one and a half times around the lower end of the pile, and their pitch is never very great.

I have no reliable data at hand on which to predicate an opinion as to the real durability of metallic piles. Cast iron supporting members, and, I think, sheet piling, have been used in England for upwards of 50 years, without evidencing any present appearances of decay even at the water line; and solid wrought iron piles show an equally sound and durable condition after an exposure of 16 years. A patent was issued to a Mr. Mosely, some few years ago, for an improvement in cast iron hollow cylindrical piles, open at the lower end, with the usual form of cutting edge, like Mr. Brunel's, or closed with a solid gimlet like screw and point. In specifying the use of the open end piles, the patentee proposed to simply screw them sufficiently deep to secure lateral stability, then to remove the displaced material from the interior, and drive an iron bound and short timber pile through the interior of the iron pile *down to the bed rock*, and then fill the latter pile with concrete. I am not aware that the system was ever practically verified, although it seems to me some of the so-called Mosely piles were used in or around the city of Boston. Solid wrought iron piles on the Mitchell principle have been driven or screwed to a depth of over 50 feet—I think 53 feet. The usual depth to which they are driven is always controlled by the character of the material and the nature of the load they are intended to carry—its average varies between 9 and 28 feet. As to the present cost of such work, very few are as eminently qualified to form an intelligent opinion as yourself. As regards the best and most economical plan for the work in question, I hardly know what to say. Of course it would be both unkind and unprofessional in me to recommend any plan that would tend to interfere with the views of the present engineer of the work, should one be already employed.

The following occur to me as economical and durable, combined with simplicity of detail and ease of construction, and are based upon an assumed depth of water of 6 to 8 feet, and an overlaying deposit of mud on the bed rock from 5 to 6 feet deep:—

First. Dredge the site to the bed rock. Build on the shore, in sections, and float into place, or build in the water on the site a bulkhead or crib, using 12×12 inch sound *hemlock* or *spruce* timber, previously treated by the "Seely-Pelton" process, and thoroughly fastened with inch square wrought iron drift bolts, 21 inches long, and driven about 3 feet apart. Tie laterally with the same timber, 6×12 inch, and of such length as the dimensions of the work may require. Separate the ties with bolsters of the same timber, 6×12 inch, 3 feet long, never spaced over 12 feet apart, and thoroughly fastened at all intersections with the drift bolts already specified. Fill with broken stone or quarry refuse to any height desired. I have purposely recommended hemlock or spruce timber because of their economy in point of first cost, and because, when treated by the "carbolic-acidizing" process, they become as desirable and lasting as any of the harder and higher priced woods.

Second. Construct square columns of masonry laid in cement mortar—say 3 feet square under the coping—the latter 18 inches thick and projecting 6 inches on all sides; give the sides of the columns a bâtir or talus of 1 inch per foot; locate the columns 25 or 30 feet apart centers; build them in little caissons open at top, and whose bottoms should form a permanent platform for the masonry to rest upon, made of two courses of 12×12 inch timber previously specified, laid at right angles, and bolted at each intersection; dredge the sites as before, float into place, finish, and remove the caisson sides for use on other columns. Carry the superstructure on compound girders, or **I** beams, of required length and depth.

Third. Similar to the foregoing, except that the stone in the columns may be laid dry (without mortar) by a diver, until low water line is reached, then finished in cement mortar to coping. Of course the foregoing are suggested without any knowledge on my part of the local surroundings, or of the demands or views of the inhabitants of the place.

Trusting what I have said herein may be of some slight service to you, I am, etc.,

Very sincerely yours,
G. HOWARD ELLERS, Chief Engineer.

TROY & WEST TROY BRIDGE CO.:
CHIEF ENGINEER'S OFFICE,
Troy, N. Y., June 10, 1874.

Franklin Institute.

HALL OF THE INSTITUTE, Sept. 16th, 1874.

The meeting was called to order at 8 P. M., the President, Coleman Sellers, in the Chair.

The Secretary being absent, the President appointed J. B. Knight as Secretary *pro tem.*

The minutes of the last regular meeting, held June 17th, 1874, and the minutes of the special meeting, held June 22d, were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at their stated meeting, held on the 9th, donations to the Library had been received as follows:—

History of New Sweden, or the settlements on the River Delaware. By Israel Acrelius. From the Historical Society of Penna.

Proceedings of the Academy of Natural Sciences of Philada. Part 1, January, February, March, 1874. From the Society.

Annales des Ponts et Chaussées, for November and December, 1873. Paris. From the Editor.

Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins. Vol. 26, 1874; parts 6 and 7. Vienna. From the Society.

Assaying by the Spectroscope. Experiments made in the U. S. Mint, Philada. From Alex. E. Outerbridge, Jr.

Denkschrift zur Erinnerung an die Fünf-und-zwanzigjahrige. Grundungs-Feier des O. I. and A. Vereins, Vienna, 1873. From the Society.

Cincinnati Industrial Exposition. Rules and Lists of Premiums for 1874. From the Board.

Report of the Board of Commissioners Fourth Cincinnati Industrial Exposition, 1873. From the Board.

Jahrbuch der K. K. Geologischen Reichsanstalt. Vol. 24, January February and March, 1874. Vienna. From the Society.

Verhandlungen der K. K. Geologischen Reichsanstalt, No. 1, 1874. From the Society.

Zeitschrift des Architekten und Ingenieur Vereins zu Hanover. Vol. 20, No. 1, 1874. From the Society.

Annales de Chimie et de Physique. Vol. 1, April, 1874. Paris. From the Editor.

Bulletin de la Société d'Encouragement pour L'Industrie Nationale. No. 5, 1874. Paris. From the Society.

Tables des Comptes Rendus des Seances de l'Academie des Sciences. Vol. 77, 1874. Paris. From the Academy.

Journal of the Society of Arts. Vol. 22, from No. 1119 to 1123, inclusive. London, 1874. From the Society.

Monthly Report of the Chief Engineer of the Manchester Steam Users' Association, for January, February, March and April, 1874. From the Association.

Improvements in Steam Engines, with Diagrams. By John Haupt, of Pennsylvania. From the Author.

An Elementary Treatise on Mechanics. Intended for the use of Colleges and Universities. By W. Whewell, D. D. From Mr. C. A. Evans.

Monthly Report of the Chief Engineer of the Manchester Steam Users' Association for the Prevention of Steam Boiler Explosions, for May, 1874. From the Association.

Proceedings of the Royal Geographical Society of London. Vol. 18, No. 3, 1874. From the Society.

Third Report of the Meteorological Office of the Dominion of Canada, for the fiscal year ended June 30th, 1873. By G. T. Kingston, M. A., Superintendent.

Proceedings of the Scientific Meetings of the Zoological Society of London for the year 1873. Part 3, June—December, and Part 1, 1874, containing papers read in January and February. From the Society.

Proceedings and Memoirs of the Literary and Philosophical Society of Manchester, 1868–9. Vol. 3 to 1872–3. Vols. 2 and 4. Third Series. From the Society.

Annales des Ponts et Chaussées, for February and March, 1874. Paris. From the Editor.

Monthly Notices of the Royal Astronomical Society. Vol. 34, No. 8, June, 1874. From the Society.

American Ephemeris and Nautical Almanac for the year 1877. Washington. From the Bureau of Navigation.

Annales des Ponts et Chaussées, for April, 1874. Paris. From the Editor.

Annales de Chimie et Physique, for June, 1874. Paris. From G. Masson, Editor.

Proceedings of the Philosophical Society of Glasgow, 1873–74. Vol. 9, No. 1. From the Society.

Les Cristalloïdes a Directrice Circulaire. Paris. From Le Cte. Léopold Hugo.

Théorie des Cristalloïdes Elementaires. Paris. From Le Cte. Léopold Hugo.

Tables for finding the Latitude of a Place by Altitudes of Polaris. Washington, 1874.

Journal of the Royal Geographical Society. Vol. 43, 1873, London. From the Society.

Monthly Report of the Chief Engineer of the Manchester Steam Users' Association for the Prevention of Steam Boiler Explosions, for June, 1874. From the Association.

Journal of the Chemical Society of London, for May, June, and July, 1874. Vol. 12. From the Society.

Journal of the Statistical Society of London. Vol. 37, Part 2. June, 1874. From the Society.

Geological Survey of Indiana, for 1873. With Maps. From E T. Cox, State Geologist.

Second Annual Message of William S. Stokely, Mayor of the City of Philadelphia, with accompanying Documents, May 14th, 1874. From Hon. Wm. S. Stokely, Mayor.

Report on Weather Telegraphy and Steam Warnings presented to the Meteorological Congress at Vienna, in September, 1873. London. From the Meteorological Committee.

Report of the Meteorological Committee of the Royal Society, for the year ending 31st December, 1873. London. From the Meteorological Committee.

Iron Works of the United States, 1874. Phila. From the Amer. Iron and Steel Assoc.

Annales des Ponts et Chaussées, for May, 1874. Paris. From the Editor.

Metropolitan Museum of Art. New York. 1874.

Eighty-sixth Annual Report of the Regents of the University of the State of New York. Albany, 1873. From the Regents of the University.

Twenty-third Annual Report of the Regents of the University of the State of New York on the Condition of the State Cabinet of Natural History, &c. Albany, 1873. From the Regents.

Twenty-fourth Annual Report on the New York State Museum of Natural History, by the Regents of the University of the State of New York. Albany, 1872. From the Regents.

Fifty-sixth Annual Report of the Trustees of the New York State Library for the year 1873. Albany, 1874. From the Trustees.

Twenty-fifth Annual Report on the New York State Museum of Natural History, by the Regents of the University of the State of New York. Albany, 1873. From the Regents.

Twentieth, Twenty-first and Twenty-second Annual Reports of the Regents of the University of the State of New York on the condition of the State Cabinet of Natural History, &c., 1868–69 and 1871. From the Regents.

Report of the Commissioner of Agriculture for the years 1871 and 1872. Washington. From the Commissioner.

Proceedings of the Royal Geographical Society. Vol. 18, Nos. 4 and 5. London. From the Society.

Proceedings of the American Philosophical Society. Vol. 14, January to June, 1874, No. 92. Philadelphia. From the Society.

Circular of Information of the Bureau of Education. No. 2, 1874. Washington. From the Board of Education.

Annales des Ponts et Chaussées, for June, 1874. Paris. From the Editor.

The Actuary also announced that the Board had approved the arrangement made by the Committee on Instruction with Prof. Haupt, of the University of Pennsylvania, to conduct the drawing school during the coming sessions.

The Chairman of the Committee on Exhibition reported progress, and stated that having been placed in possession of the building at an earlier date than was anticipated, the preparations for the reception of goods were completed a week earlier than the time advertised. The number of applications for space has been very large, and nine-tenths of the available space has been already allotted. Hence many persons who have delayed their applications will undoubtedly be disappointed.

The Secretary pro tem. presented an artist's rotary color stand, the invention of Mr. Samuel James, of this city, a full description of which will be found elsewhere in this number of the JOURNAL.

The President stated that he had been waited on by some of the members of the Commission appointed by the United States government to make experiments towards determining the cause of Steam Boiler Explosions. Some changes have been recently made in this Commismission, and Prof. Joseph Winlock, of Harvard, has been placed at its head. He was selected for his knowledge of the means of exact measurement, and his appreciation of the necessity of a correct record of such experiments. The object of the Commission seems to be to consider all the theories that have been advanced, to test each one carefully, and to eliminate from the test all that cannot be sustained; then to collect all the information of a useful, practical character that is possible. They speak in terms of the highest respect of the experiments conducted by the Franklin Institute, and say they assume them as a basis upon which to build a still more useful superstructure. But the Franklin Institute, at that time, lacked the means which are now at the disposition of scientists for the careful noting of physical phenomena. They wished their work mentioned to the members of the Franklin Institute, and a request made that if any members of the Institute were cognizant of any reliable means of reading in a bomb proof, some distance removed from the boiler to be exploded, the various conditions of heat, of water, of fire, and of steam, and the various conditions of pressure, as also of motions of parts of the boiler, under strain, they would esteem it a favor if communication would be held with the Commission on the subject. He also stated that there had been very few responses to the circular of the Commission of Sept. 11th, 1873, asking the aid of scientific men, and suggested a committee on this subject, to co-operate with them, and to collect and transmit such information as the members might have to communicate.

Professor Barker said that the Franklin Institute should not be backward in lending its assistance in a work of so much importance, and especially as it was a continuance by the government of what the Institute inaugurated many years ago; the report then made being still regarded as the highest authority on the subject. On motion of Prof. Barker it was

Resolved, That a Committee of three be appointed to co-operate with the Commission.

The Chair appointed on this Committee, Prof. Geo. F. Barker, Robt. Briggs and J. B. Knight; and on motion of Mr. Close, the President, Coleman Sellers, was added.

The President stated that one member of the Commission was in possession of one copy of the original report of the Committee on the causes of Steam Boiler Explosions, and that he had asked if the Institute intended republishing it.

The President also stated that he believed that the republication of the Report might be made profitable, as there would, no doubt, be a demand for it.

On motion of Mr. Orr the attention of the Committee on Publication was called to the propriety of republishing the original Report of the Committee on Steam Boiler Explosions.

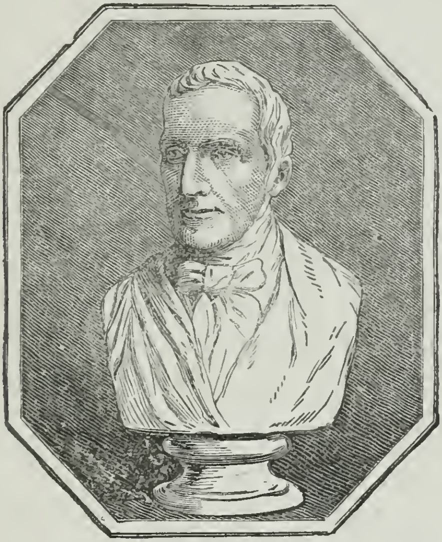
On motion, the meeting then adjourned.

J. B. Knight, *Secretary*, *pro tem.*

Civil and Mechanical Engineering.

THE MESSRS. STEVENS, OF HOBOKEN, AS ENGINEERS, NAVAL ARCHITECTS AND PHILANTHROPISTS.

By Professor R. H. Thurston.



COL. JOHN STEVENS.

The biography of the greatest Engineers, in some respects, that America has yet produced, is still to be written.

Col. John Stevens, of Hoboken, was undoubtedly the greatest engineer and naval architect living at the beginning of the present century.

Without having made any one superlatively great improvement in the mechanism of the steam engine, like that which gave Watt his fame; without having the honor of being the first to propose navigation by steam, or steam transportation on land, he exhibited a far better knowledge of the science and of the art of engineering than any man of his time, and he entertained and urged more advanced opinions and more statesmanlike views, in relation to the economical importance of the improvement of the steam engine, both on land and water, than seem to have been attributable to any other leading engineer of that time.

Col. Stevens was born in the city of New York, in 1749. He was of English descent, his grandfather having come to this country early in the eighteenth century, settled in New York, and married Anne Campbell, granddaughter of Lord Neil Campbell. This gentleman died at Perth Amboy, to which place he had removed after marriage, leaving a son, president of the council of New Jersey.

This son, the father of Col. John, married Miss Elizabeth Alexander, a descendant of one of the first settlers of the state of New Jersey.

Col. John, although as it is stated born in New York, was a resident of New Jersey, and married Miss Rachel Cox, a daughter of John Cox, a prominent citizen of the state, living at Bloomsburg, N. J.

The late Dr. Charles King, then the distinguished President of the Columbia College, thus referred to this great man in a lecture describing the "Progress of the City of New York:"

"Mr. Stevens' attention was first turned, or rather the bent of his genius was developed and directed, towards mechanics and mechanical philosophy, by the accident of seeing in 1787 the early and as now may be said imperfect steamboat of John Fitch, navigating the Delaware river. He was driving in his phaeton on the banks of the river, when the mysterious craft, without sails or oars, passed by. Mr. Stevens' interest was excited—he followed the boat to its landing—familiarized himself with the design and the details of this new and curious combination, and from that hour became a thoroughly excited and unwearied experimenter in the application of steam to locomotion on the water, and subsequently on the land.

"Having been brought by close family connection, into intimacy with Robert R. Livingston (the Chancellor of this state, who married the sister of Col. Stevens,) he induced Mr. L. to join him in these investigations, and they were persevered in at great cost and with little immediate success till Chancellor Livingston, in 1801–2, was sent as minister to France.

"So much, however, was the Chancellor encouraged by the experiments then made, that as early as 1798 he obtained from the Legislature of New York, an exclusive grant for the use of steam on the waters of New York. This, however, became forfeit by the failure to avail within the limited time of its privileges.

"But previously to the Act of '98, the Legislature of New York had, as early as 1787, granted to *James Rumsey* and to *John Fitch* the exclusive right to navigate the waters of the State with steam-propelled vessels; and on the 9th of January, 1789, John Stevens petitioned the Legislature for a like grant—nothing having resulted from the preceding ones. Mr. Stevens in his petition says that, 'to the best of his knowledge and belief his scheme is altogether new, and does not interfere with the inventions of either of the other gentlemen who have applied to your honorable body for an exclusive right of navigating by means of steam.' The petitioner adds that he 'had made an exact draught of the different parts of his machine, which, with an explanation thereof, he is ready to exhibit.' The prayer of the petition was unsuccessful; but these draughts should be among the papers of the late Col. Stevens, and at this day would be curious.

"Mr. Stevens, meanwhile, never renounced his experiments, nor despaired of success, and in 1804 he actually constructed a *propeller*, (a small open boat, worked by steam), with such decided success, that he was encouraged to go on and build the *Phœnix* steamboat, on his own plan and model, and had her ready almost contemporaneously with, but a little after, the first steamboat of Fulton, the *Clermont*. The success of the Clermont entitled Mr. Fulton and Chancellor Livingston, who was co-operating with Fulton, to the benefit of the law, which had been revived by the State of New York, granted a monopoly of the waters of the State, and thus Mr. Stevens' steamboat was excluded from those waters. On the Delaware, however, and on the Connecticut, he placed boats; and his eminent son, Robert L. Stevens, having embraced his father's views, was now at work with him to improve the known, and invent new resources for accelerated steam conveyance.

"In 1812, just before the commencement of the war with England, and when this State," (New York) "was first addressing itself to the thought of connecting the waters of the lakes with those of the ocean by the Hudson, a thought, very rapidly matured in the sequel, by the delays and *now* incredible cost in transporting troops, artillery and munitions during the war from the sea-board to the lakes, Col. Stevens put forth a pamphlet urging that railroads and steam carriages should be preferred to canals and canal-boats.

"At that day, not a *locomotive* existed in the world, and the only railroads were those few, and short tram-roads, as they were called in England, connecting for the most part coal mines with canals, or other water transportation, and upon which carriages with the ordinary wheels turning upon their axle-trees were drawn by horses. The carriages were prevented from running off side-ways by a flange raising some inches above the outer edge of the flat rail. In this state of knowledge and experience of railroads it was that, in 1812, Col. Stevens made public, his extraordinary and most sagacious view and accurate calculations respecting, not only the feasibility of applying steam to locomotion on land, but the precise mode of such application; its cost, and its almost illimitable advantages. It seems all but impossible to realize the fact, when carefully reading his description of the railway, of the locomotive, of its wheels made fast to the axle, and revolving not *on* but *with* it, and held by flanges on the inner periphery, from flying off at a tangent, of a whole train, or 'suit,' as he calls it, of railway carriages, 'all firmly attached to each other, and pursuing the same direction;' and of the possible speed they might attain of 40 or 50 miles an hour, but that probably 'it would in practice be found convenient not to exceed 20 or 30 miles an hour;' it seems I repeat, almost impossible to realize the fact that, at that day no locomotive existed except in the creative and ingenious mind of the writer; and that no railroad, such as he needed for his unrevealed plan had ever been laid down.

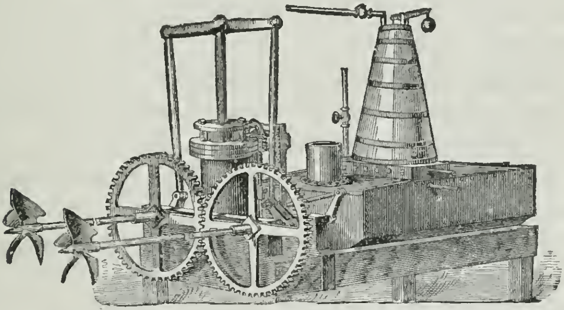
"If he had seen then, what he lived to see afterwards, and from the handiwork and genius mainly of his son Robert, on the Camden and Amboy Railroad, the spectacle, ever impressive, however frequently witnessed, of long trains of cars sweeping on with the rapidity of the pigeon's flight, he could not have described with more absolute accuracy all the details of such a train, such a road, and such a locomotive, than is done in the prophetic pamphlet of 1812.

"He was treated as a 'visionary projector.' Time has vindicated his claim to the character of a far-seeing, accurate and skillful practical experimentalist and inventor; and who can estimate, if at that day, acting upon the well considered suggestion of President Madison, 'of the signal advantages to be derived to the United States from a general system of internal communication and conveyance,' Congress had entertained Col. Stevens' proposals, and after verifying by actual experiment upon a small scale, the accuracy of his plan, had organized such a 'general system of internal communication and conveyance;' who can begin to estimate the inappreciable benefits that would have resulted therefrom to the comfort, the wealth, the power and above all to the absolutely impregnable union of our great Republic and all its component parts?

"All this, too, Col. Stevens embraced in his views; for he was a statesman, as well as an experimental philosopher; and whosoever shall attentively read this pamphlet will perceive that the political, financial, commercial, and military aspects of this great question were all present to Col. Stevens' mind; and he felt that he was fulfilling a patriotic duty when he placed at the disposal of his native country, these fruits of his genius.

"The offering was not accepted. The THINKER was ahead of his age; but it is grateful to know that he lived to see his projects carried out, though not by the government; and that, before he finally, in 1838, closed his eyes in death, at the age of 89, he could justly feel assured that the name of *Stevens*, in his own person and that of his sons, was imperishably enrolled among those which a grateful country will cherish."

The whole life of Col. Stevens, as remarked by the same writer, "was devoted to experiments, at his own cost, for the common good."



MACHINERY OF TWIN SCREW STEAMER OF 1804.

A model of the little steamer built in 1804, is preserved in the lecture room of the department of mechanical engineering at the STEVENS' INSTITUTE OF TECHNOLOGY and the machinery itself, consisting of a high pressure "sectional" or "safety" tubular boiler as it would be called to-day, a high-pressure condensing engine with rotating valves, and with twin screw propellers is given a place of honor in the model room or museum, where it contrasts singularly with the mechanism contributed to the collection by manufacturers and inventors of our own time. The hub and blade of a single screw, also used with the same machinery, is also to be seen there.

The British Patent on the boiler, issued to John Cox Stevens, a son of the inventor, is also to be seen in the Relic corner of the lecture room of the writer.

A water tubular boiler, also, made for a small locomotive built somewhat later is another relic testifying to the ability of this great man. In his published pamphlet on railroads, Col. Stevens writes May 15th, 1812, "I can see nothing to hinder a steam carriage from moving on these ways, with a velocity of one hundred miles per hour," and, in a foot note, "This astonishing velocity is considered here as merely possible. It is probable that it may not in practice be convenient to exceed twenty or thirty miles an hour.

"Actual experiments, however, can alone determine this matter, and I should not be surprised at seeing steam carriages propelled at the rate of forty or fifty miles an hour."

Col. Stevens designed a peculiar form of iron clad in the year 1812, which has been since reproduced by no less distinguished and successful an engineer than the late John Elder, of Glasgow, Scotland. It consisted of a saucer shaped hull, carrying a heavy battery and plated with iron of ample thickness to resist the shot fired from the heaviest ordnance then known. This vessel was secured to a swivel, and was anchored in the channel to be defended. A set of screw propellers driven by steam engines and situated beneath the vessel, where they were safe against injury by shot, were so arranged as to permit the vessel to be rapidly revolved about its centre. As each gun was brought into line of fire it was discharged, and was then reloaded before coming around again. This was probably the earliest embodiment of the now well established "Monitor" principle. This was probably the first iron clad ever designed.

This great engineer and inventor was therefore far in advance of his time. The sectional steam boiler only just becoming a standard type; high pressure steam with condensation has just become generally adopted; the screw only came into use forty years later when Ericsson, Smith and Woodcroft came forward with it, and twin screws are hardly yet familiar to engineers. The revolving battery protected by iron plating is another of what are generally considered recent devices; and the peculiar Stevens revolving ship is reproduced by Elder sixty years later.

The sons of Col. John Stevens assisted their father in his work and inherited their father's mechanical skill.

The designer of the celebrated Stevens Battery was one of these sons, and the name of Robert L. Stevens is not less famous than that of John Stevens.

ROBERT L. STEVENS.

He took an active part with his father, very early in life, and in 1808, went around by sea from New York to Philadelphia with Captain Bunker, in the "Phœnix," the first sea voyage which was ever made under steam.

It was Robert L. Stevens who became so well known as a successful steamboat builder, and as one of the originators of the best lines of steamers on the Delaware and Connecticut, and, after the expiration of Fulton's monopoly, on the Hudson. Much of his best work was done during his father's life-time.

He made many extended and most valuable as well as interesting experiments on ship propulsion, expending much time and large sums of money upon them, and many years before they became generally admitted, he had arrived at a knowledge not only of the laws governing the variation of resistance of excessive speeds, but he had determined and had introduced into his practice those forms of least resistance and those graceful water lines which have only recently distinguished the practice of other successful naval architects.

Referring to his invaluable services, President King, who seems to have been the first to thoroughly appreciate the immense amount of original invention, and the surprising excellence of the engineering work of this family, says, in 1851: "The extent, variety and value of Mr. R. L. Stevens' labors and inventions in mechanics, should have more fitting commemoration than can be given in any passing notice by one unskilled, as is the writer of this, in the mechanical arts. Yet he cannot suffer this allusion to Mr. Stevens to go forth without attempting at least to enumerate some of the many services and ingenious inventions and appliances of that gentleman in steam, in gunnery, and in mechanics. From the time when a mere boy, in 1804–5, he was zealously working in the machine shop at Hoboken, up to the passing hour, he has given his time, his faculties, and his money, to what may be justly described as *experimental philosophy*, and the results have been of great public benefit. Of some of them, the following chronological record may bear witness:

"1808. Hollow or concave water lines in the bow were introduced for the first time in the steamboat Phœnix—the first steamboat that ever breasted the ocean; these lines, under the name of 'wave lines,' are now, as I understand, claimed abroad as a recent English application. On the same vessel, in 1809, he first used *vertical buckets* on pivots.

"1809. Suspended the projected guard beam by iron rods from above—now universal in river steamers.

"1813–14. The war with England being then in progress, he invented, after numerous and most hazardous experiments, the *elongated shell*, to be fired from ordinary cannon. Having perfected this invention, he sold the secret to the United States, after making experiments to prove their destructiveness, so decisive as to leave no doubt of the efficacy of such projectiles. One of these experiments was made at Governor's Island, in the presence of officers of the army, when a target of white oak, four feet thick and bolted through and through with numerous iron fastenings, was completely destroyed by a shell weighing 200 lbs. and containing 13 lbs. of best battle powder; this solid mass of wood and iron was torn asunder; the opening made was large enough, as the certificate of the officer commanding, Col. House, stated, for a man and horse to enter.

"These shells are free from the danger accompanying ordinary shells, for they are *hermetically sealed*, and suffer no deterioration from time. Some of these, after being kept 25 years, by way of proving their safety till needed and as needed, were tested by exploding gunpowder under them, and then were taken to high places and let fall on rocks below, and all without causing them to explode.

After this they were plunged into water, and then being put into the cannon, were fired, and upon striking the object, exploded with devastating effect.

"1813. First to fasten planks and braces of steamboats (in the Philadelphia) with screw bolts, and to place diagonal knees of wood and iron inside of them.

"1815. First to use steam expansively in steamboat Philadelphia.

"1818. First to burn anthracite coal in a *cupola* furnace, and subsequently to introduce this fuel in fast steamers—the Passaic being the earliest to use it.

"1822. To substitute for the heavy, solid cast-iron walking-beam of steamboats, the skeleton wrought-iron walking-beam (in the Hoboken), now in universal use.

"1824. First to place the boilers on the guards, and to divide in steamboat Trenton the buckets on the water-wheel.

"1827. First on steamboat North America to apply successfully artificial blast to the boiler furnace by means of blowers, and in the same boat to apply what is technically known as the *hog frame*, now general in fast boats, consisting of the large timbers on the sides to prevent the boat from bending in the centre, or as it is called, being *hogged.*

"1828. First to apply the steel spring *bearings* under centre of the wheel shaft of the steamer New Philadelphia.

"1832. First to introduce in the New Philadelphia perfect *balance valves*, now in general use in steamboats, which enabled one man to work the largest engine with ease. In the same year he used braces to the connecting rod, thus strengthening it and preventing its tremulous motion.

"1832–3. Constructed a boat (between Camden and Philadelphia) capable of navigating through solid, heavy ice. In the same year he constructed and introduced tubular boilers, having the fire under the bottom and returning through the tubes.

"1840. Improved the packing of pistons for steam engines by using the pressure of steam instead of hemp, steel springs, india rubber, etc., to retain the metallic packing ring against the surface of the cylinder. One of these rings which has been in use on board steamer Trenton since 1840, is at this day in good order.

"1841. The *Stevens Cut-off*, by means of main valves worked by two eccentrics, invented by R. L. Stevens and his nephew (for mechanical ingenuity and skill run in the blood) F. B. Stevens; these are generally used now in the river boats and in the ocean steamers built in New York. In the same year he invented and applied on the Camden and Amboy railroad the double-slide cut-off, for locomotives and large engines; and improved locomotives for transporting goods, etc., by using eight wheels, and with increased adhesion was enabled to turn short curves with little friction on the flanges; also used *anthracite* as a fuel to great advantage on the heavy engines, weighing 24 tons, with wheels of 42 inches diameter, cylinders of 18 inches, and 34 inch stroke.

"1842. Having contracted to build for the United States government a large war steamer, shot and shell proof, R. L. Stevens built a steamboat at Bordentown for the sole purpose of experimenting on the forms and curves of propeller blades, as compared with side-wheels, and continued his experiments for many months, the result of which we may yet hope to see in an iron war steamer that will be *invincible*, and should be so named. While occupied with this design he invented about 1844, and took a patent for, a mode of turning a steamship of war on a pivot, as it were, by means of a cross propeller near the stern, so that if one battery were disabled, she might in an instant almost, present the other.

"1848. This year he succeeded in advantageously using *anthracite* in fast passenger locomotives.

"1849 witnessed the successful application of air under the bottom of steamer *John Neilson*, whereby friction is so much diminished, that she has actually gone at the rate of 20 miles an hour; this was the invention of R. L. Stevens and F. B. Stevens. The *John Neilson* also has another ingenious and effectual contrivance of R. L. Stevens, first used in 1849, for preventing ill consequences from the foaming of the boiler. In conclusion of this dry and imperfect chronological recital of some of R. L. Stevens' contributions to the mechanic arts, to public convenience and national power, as well as renown, it must be added that Mr. Stevens is himself the modeller of all the vessels built by or for him, and that many of our fastest yachts are of his moulding; and especially the *Maria*, which beat without difficulty the victorious America, which in her turn carried the broom at her mast-head through the British Channel, distancing all competitors, as she continues to do, I believe, under her new owner in the Mediterranean.

"Of such a man, not only the mechanics of our city" (New York) "among whom he has worked, and is well known, but the nation may well be proud."

The Camden and Amboy railroad was projected and largely sustained by the aid, both pecuniary and other, of the Messrs. Stevens. The locomotives were built from the designs of Robert L. Stevens, some at the works in Hoboken, and some in English workshops. It was here that he introduced the T-rail, and when his design was pronounced an impossible one to roll, he himself went abroad and showed that it could be done and how.

In 1833, in a letter now framed and carefully preserved in the "Relic Corner" of the Department of Engineering in the STEVENS INSTITUTE OF TECHNOLOGY, Robert Stephenson writes to Robert L. Stevens, deprecating the general inclination of American Engineers to build light locomotive engines, and stating that he had completed the design of an engine,—of which he gave a neat sketch, made to scale,—which weighs nine tons, and is capable of hauling "one hundred tons dead load sixteen or eighteen miles an hour on a level." He urges Mr. Stevens, whom he seems to consider an engineer of correct views, to assist him in effecting sales.

Mr. Stevens' experiments on the effect of the impact of shot and shell upon iron plating were commenced very early, and were carried on at great expense of time and money. As early as 1837 he had perfected a plan of an iron clad war vessel, and in August, 1841, his brothers James C. and Edwin A. Stevens, representing Robert L., addressed a letter to the Secretary of the Navy, proposing to build an iron clad vessel of high speed, with all its machinery below the water line, and submerged screw propellers.

The armament was to consist of the most powerful rifled guns, loading at the breech, and provided with elongated shot and shell.

After some delay, during which Mr. Stevens and his brothers were engaged with their experiments and in perfecting their plans, a contract was made in 1843, and the keel of an iron clad was laid down in a dry dock which had been constructed for the purpose at great cost.

This vessel was to have been 250 feet long, of 40 feet beam, and 28 feet deep: The machinery was designed to furnish 700 indicated horse power. The plating was proposed to be 4½ inches thick,—the same weight of armor as was adopted ten years later by the French for their comparatively rude constructions.

In 1854, such marked progress had been made in the construction of ordnance that Mr. Stevens was no longer willing to proceed with the original plans, fearing that were the ship completed, it might prove not invulnerable and might throw some discredit upon its designer as well as upon the navy of which it was to form a part.

The work, which had, in those years of peace, progressed very slowly and intermittently, was therefore stopped entirely, the vessel given up and in 1854 the keel of a ship of vastly greater size and power was laid down.

The new design was 415 feet long, of 45 feet beam and of something over 5000 tons displacement. The thickness of armor proposed was 6¾ inches,—2¼ inches thicker than that of the first French and British iron clads,—and the machinery was designed by Mr. Stevens to be 8624 indicated horse power, driving twin-screws and propelling the vessel twenty miles or more, an hour.

As with the preceding design, the progress of construction was intermittent and very slow. Government advanced funds and then refused to continue the work, successive administrations alternately encouraged and discouraged the engineer and he finally, cutting loose entirely from all official connections, went on with the work at his own expense.

The remarkable genius of the elder Stevens was well reflected in the character of his son, and is in no way better exemplified than by the accuracy with which, in this great ship, those forms and proportions both of hull and machinery were adopted which are to-day, a score of years later, recognized as most correct under similar conditions.

The lines of the vessel, as shown on plate I. in the descriptive article already published in this JOURNAL, for September, are beautifully fair and fine and are what J. Scott Russell has called "wave lines," or trochoidal lines, such as Rankine has shown to be the best possible for easy propulsion. The proportion of length to midship dimensions is such as to secure the speed proposed with a minimum resistance and to accord closely with the proportions arrived at and adopted by common consent in past trans-oceanic navigation by the best,—not to say radical,—builders.

Even in the minor details of his machinery Mr. Stevens had, by careful experiment, determined for himself, and had adopted in his practice, proportions which were only hit upon by the majority of engineers many years later. In much of this experimental work, including his researches in naval science, he was assisted by his

Nephew Francis B. Stevens, still the superintendent of the establishment of the Camden and Amboy R. R. at Hoboken.*

Mr. Stevens conducted his experiments and did his own work with great secrecy as it was considered a matter of national importance that no knowledge of his work should reach foreign powers, and Mr. Norman Scott Russell who was probably the first to obtain any accurate information relating to the ship, stated before the British "Institute of Naval Architects," that, in 1858 or 1860 few persons knew "that Mr. Stevens had made experiments upon armor plates for ships of war as early as the year 1816, and nobody in this country" (Great Britain) "entertained the slightest suspicion that the American Government had concluded a contract with the Messrs. Stevens, the fathers of this new system, to construct an iron plated battery as early as 1843, though the commencement of this vessel was delayed by official interference until some years later. So well indeed had they kept their secret that the late Sir Howard Douglass, who took so deep an interest in the improvement of the Navy, and prided himself on being kept well informed of all that was being done in the naval or military matters of foreign countries, wrote as late as 1860, that no iron-cased vessel was built, or being built in the United States."

The guns proposed in 1843 were large for that time, "64 pounders" and the principle, now recognized as a cardinal principle, "a smaller number of the largest guns, rather than a larger number of small guns," was upheld from the beginning by Mr. Stevens. The larger vessel was designed for the heaviest guns that could be constructed at the time. These immense guns were to be mounted on turntables and worked very much as the guns of the "monitors" are handled.

The death of Robert L. Stevens occurred when this larger vessel had advanced so far towards completion that the hull and machinery were practically finished, and it only remained to add the armor-plating, and to decide upon the form of fighting house, and upon the number and size of guns.

The construction of the vessel, which had proceeded slowly and intermittently during the years of peace, as successive administrations had considered it necessary to continue the payment of appropriations, or had stopped it temporarily in the absence of any apparent immediate necessity for its continuance, was again interrupted by his death in the year 1856.

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* The same engineer to whose intelligence, energy and public spirit, conjoined with the liberality of the United Railroads of New Jersey, we are indebted for that knowledge of the causes and methods of steam boiler explosions which was acquired in 1871, and of which extended accounts appeared in this Journal.

EDWIN A. STEVENS.

His brothers, J. C. and E. A. Stevens, had taken an active and intelligent interest in the great scheme, attempted to secure from the government authority to complete the ship.

The last named addressed several letters to the Navy Department on the subject, but received no substantial encouragement, although offering to complete the vessel at his own expense, and agreeing:

"1st. That she shall be impenetrable to the most destructive missile fired from the most powerful gun (with its ordinary service charge) now used in our own or in any European naval service, to be tried upon her at short range—say 220 yards.

"2d. That she shall have greater speed than any other iron-clad war steamer in the world.

"3d. That she shall be more manageable and more quickly turned and manœuvered than any other large armed sea-going steamer.

"4th. That she shall have an armament capable of throwing a broadside at least equal to that of any ship now afloat."

The vessel was to be tried on completion, and accepted and paid for by the government only when these conditions were fulfilled. But even these terms the government seemed indisposed to accept. A board appointed to examine the vessel, reported a description of the vessel with criticisms of some of its details. Mr. Stevens presented to the government the favorable professional opinions of nearly every distinguished engineer and shipbuilder in the country, including R. L. Loper, Samuel Harlan, Jacob S. Neafie, Theodore Birely, Washington Jones, Messrs. Coryell and Erastus W. Smith, and also Professor Henry.

Mr. Stevens, to settle a doubt expressed as to the value of the plans proposed for loading and working the guns by steam—one of Robert L. Stevens' most important inventions—built a small vessel, the "Naugatuck," to practically demonstrate its efficiency in actual warfare.

This steamer was 100 feet long, 20 feet beam, and 7 feet depth of hold, with compartments at each end to receive water for the purpose of sinking her to her "fighting draught" when in action.

The name of this little vessel has become historical.

Under the command of W. W. Shippen, Esq., she took part in the engagement on the James river, during the attacks of the forces of the United States upon the defences of Richmond, and rendered valuable assistance until disabled by the explosion of the heavy Parrott rifle with which she was armed. Mr. Stevens has never received credit to which this characteristically liberal and patriotic enterprise should entitle him.

Mr. Edwin A. Stevens finally died, leaving this task still unaccomplished, and the vessel remained unfinished on the hands of his executors.

In the will of Mr. Stevens he made two bequests which testify to the public spirit and "large mindedness" of the man.

The most important was that by which he provided for the foundation of the STEVENS INSTITUTE OF TECHNOLOGY. Nearly a million of dollars was appropriated directly or indirectly to this great object, and this noble institution is a finer monument to his memory than is St. Paul's Cathedral to that of its great architect, Sir Christopher Wren.

Another provision of the will directed his executors to complete the iron clad with funds appropriated to that purpose, amounting to one million of dollars, and when completed to present the finished vessel to New Jersey, his native State.

The executors proceeded to carry out their instructions at once, appointing General McClellan engineer in charge, and, on his recommendation, Mr. Isaac Newton was engaged as assistant engineer.

Under the advice of the engineers, it was determined to make radical changes throughout, to place the vessel in proper condition to meet successfully those more formidable antagonists that recent rapid advances in naval science had rendered far more formidable than any existing at the time of the death of the designer.

The declared object had been, from the first, to set afloat a vessel that should be the most formidable vessel on the ocean.

It was therefore concluded to introduce an inner skin, transverse water tight bulk heads and coal bunkers, to build new engines, and to transform the vessel into an iron clad which, while retaining the high speed originally proposed by Mr. Stevens, should carry the heaviest ordnance yet built behind armor of unexampled thickness, and with undiminished power as a steam ram, capable of exerting that power with considerably increased economy of fuel.

The hull and machinery were altered in accordance with this plan, and the modified hull and new machinery are now in the shape described in the specifications and illustrated in the drawings already published in the JOURNAL OF THE FRANKLIN INSTITUTE.*

The sum appropriated for the completion of the vessel proving insufficient to supply armor and armament, the work of reconstruction was suspended, leaving the details of internal arrangement and the plan of armor and armament to be determined by the state of naval science when the funds required for the purpose should be secured.

It is probably very fortunate that this latitude was allowed the purchaser.

A question arising as to the real ownership of the vessel, the matter was referred to the Court of Chancery, and by act of the State Legislature a sale was ordered, the proceeds to be paid into Court to await the decision, and Governor Parker, Vice Chancellor Dodd, the Hon. W. W. Shippen and the Rev. S. B. Dod, were appointed a Commission with power to effect the sale.

What is to be the destiny of this noble vessel cannot now be even conjectured, but will soon be determined, the sale taking place on the second day of November next. As the vessel is offered either as an entirety or in parts, it is not impossible that the most celebrated of all iron plated vessels, never yet engaged in actual warfare, the fastest war steamer in the world, with its possibility of becoming the most powerful steam ram, the fleetest of torpedo ships or the most formidable of iron clads, should fall into hands of those who will convert her to mercantile use, either as a sailing vessel or a steamer, or even break up hull and machinery to obtain the exceptionally excellent material of which they are constructed.

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*See this Journal, lxviii, p. 165, Sept. 1874.

Even this would be better, however, than the purchase of the vessel by a foreign government, liable at any time to turn this remarkable product of the ingenuity and skill of one of the greatest of American mechanics against his native country. This is not unlikely to occur should our government neglect this last opportunity to secure the vessel.

The impossibility of securing the necessary appropriations to keep our naval force up to the standard which ordinary prudence should have established, or even to preserve those iron-clads already built, has had the effect of reducing us to dependence upon our fortunately efficient Torpedo Corps of the Army and Navy, and has made us comparatively powerless for offence. This fact makes it the more necessary that no opportunity should be lost to secure an effective vessel for our own naval force or to prevent such an addition to a foreign navy.

Whatever may be the result, however, the name of Robert L. Stevens will be long remembered as one of the greatest of American mechanics, the most intelligent of naval architects and as the first and one of the greatest of those to whom we are indebted for the commencement of the mightiest of revolutions in the methods and implements of modern naval warfare.

The length of this sketch will probably be admitted to be fully justified by the interest and importance of its subject. American mechanical genius and engineering skill have rarely been either promptly recognized until very recently and no excuse is required for any attempt to place such splendid work as that of the Messrs. Stevens, in a light which shall reveal both its variety and extent and its immense importance.

Said Henry Bell, nearly three quarters of a century ago, when he and Fulton and Stevens were at work on the great problem, "I will venture to affirm that History does not afford an instance of such rapid improvement in commerce and civilization as that which will be effected by steam vessels," and when it has been shown what has been accomplished in this great work by each of these several pioneers, there is no further need to attempt compliance with Milton's injunctions:—

"*   *   *   *   Build him
"A monument and plant it round with shade
"Of laurel, evergreen and branching palm,
"With all his trophies hung and acts inroll'd
"In copious legend, or sweet lyric song."

Stevens Institute of Technology,
Hoboken, N. J., September, 1874.

BELTING FACTS AND FIGURES.

By J. H. Cooper.

[Continued from Vol. lxvii, page 403.]

On the Creep of Belts.—"It is generally considered by those who have had experience in the matter, that there is a slight slip in all belts, however large they may be in proportion to the power transmitted, and however tightly they may be stretched. Perhaps in the case in which a belt is much larger than is required, it would be better to say that there is a slight *creeping*, instead of a slip, this creeping being caused by the change in tension of the belt as it moves from the tight to the slack side in passing over the pulley.

"Where belts are driven at a high velocity, it is found that the centrifugal force still further changes the ratio of speeds of the driving and driven pulleys, in some cases decreasing the tension of the belt, and in others acting in the contrary way. This may be explained in the following manner: If the pulleys over which the belt is stretched are quite close together, the two parts of the belt will be nearly straight, so that there will be little change of tension, whether the belt is at rest or in motion, and the centrifugal force diminishes the tension. If the pulleys are a considerable distance apart, the two portions of the belt will be curved, and part of the centrifugal force acts in increasing the length of the belt, and thus increases the tension, instead of diminishing it, as in the former case. In ordinary cases, where the velocity of a belt is not very great, it is probably not necessary to consider the action of centrifugal force.

"The writer is frequently engaged in making tests of machinery, and finds it convenient to obtain a record of the speed of shafts and engines. At a recent test of power in a large factory some interesting data were obtained in relation to the creeping of belts, and it is believed that these results may be of interest and value to other engineers."

The case was one in which the size of the belts was largely in excess of that actually required for the transmission of the power, and the velocity with which they moved was quite moderate. Under these circumstances it was to be expected that the difference between the actual ratio of speeds, and that which should have been obtained if there had been no slip or creep, would be less at an increased than at a diminished rate of speed, if the changes in speed were so slight as not sensibly to vary the centrifugal force. For the purposes of the test, counters were attached to the driving engine and to the shaft in a distant part of the building, the power being transmitted to that shaft by five belts. Simultaneous readings of the two counters were taken every minute for the space of an hour. The result of several of these observations for intervals of five minutes each, is given below:

Revolutions of engine.	Revolutions of shaft.	Ratio of speed.
159	417	2.623
153	397	2.595
154	403	2.617
148	383	2.588
Total....1848	4816	2.612

"It will be observed that as the speed was decreased, there was a perceptibly greater creep in the belts. It having been found advisable to increase the speed of the engine and shafting, similar tests were made, when this change was effected, and a few of the results are given below:

Revolutions of engine.	Revolutions of shaft.	Ratio of speed.
205	538	2.624
204	535	2.623
203	532	2.621
206	541	2.626
208	544	2.615
Total...2457	6432	2.618

It is generally known that there is a best speed for a belt under given conditions, and that if this speed is either increased or diminished, the tension of the belt will be diminished. It appears from these latter results that this speed was about reached by the change, so that the belts were transmitting under the most favorable conditions as regards speed.

A careful measurement of all the pulleys transmitting the power from the engine to the shaft in question, increasing their diameters by the mean thickness of the belts passing over them, shows that the actual ratio of speeds of engine and shaft should have been as 1 to 2·625, so that there was an average slip or creep, in the first case of 0·495 per cent, and in the second, of 0·267 per cent.

R. H. Buel, M. E.
80 Broadway, N. Y.

The Engineering and Mining Journal, Feb. 28th, 1874.

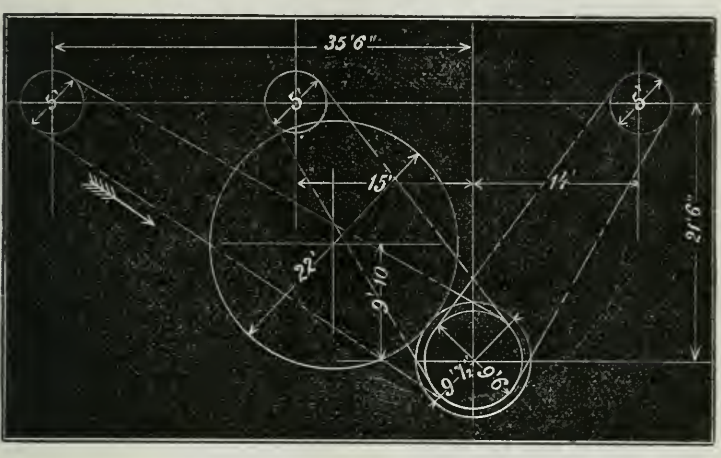
Mr. Jno. Mason, of Bulkley, Barbadoes, presents a novelty in the way of belting that he has been using for driving centrifugal machines for the past two years. He says:—"I found leather belting gave so much trouble and was so expensive that I was induced to try a belt made of raw cow's hide, simply dried in the sun, cut perfectly straight, and the joints carefully stitched (square and even) with common saddler's hemp. I find in practice that a belt of this description will last longer than from leather belts, besides being only one-fourth the cost. I am driving a line of 3 inch shafting with an 8 inch belt of this description with every satisfaction. They are now used here for driving Weston's centrifugals, as well as those of Manlove and Elliott's. I make them 2½ inches broad for driving the latter."

"*Engineering*," *June* 19*th*, 1874.

Mr. S. S. Spencer, Supt. of Conestoga Mills Nos. 2 and 3, at Lancaster, Pa., has kindly furnished me with the following particulars of the main driving belts now in use in these two mills.

Mill No. 2 is driven by an horizontal condensing Corliss engine having a 30 inch cylinder, 6 feet stroke, running 52½ revolutions per minute. The fly wheel is 22 feet in diameter, and weighs 25 tons. It has teeth on its periphery of 5·183 inches pitch, 18 inch face, and drives a "jack" 9 feet 7½ inches diameter on a counter shaft 9 feet 10 inches below the engine shaft. On this counter shaft are three

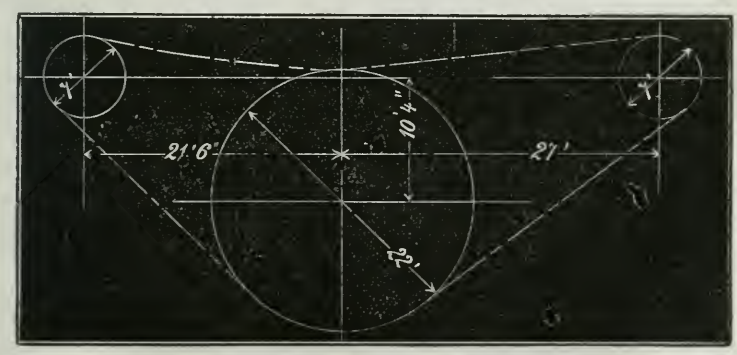
9 feet 6 inch pulleys, each driving a 5 feet pulley on the main lines as here shown. (Fig, 1.)



The belts running to right and left are each 23½ inches wide, and each transmits 125 horse power. The middle belt is 29 inches wide and transmits 175 horse power. All are of double leather.

Mill No. 3 is driven by a horizontal non-condensing Corliss engine of 28 inch cylinder, and 5 feet stroke, running 50½ revolutions per minute, having a 22 feet diameter fly wheel pulley of 17 tons weight.

Two 14½ inch double leather belts on the fly wheel run to right and left, driving 7 feet pulleys on the line shafts, thus: (Fig. 2.)



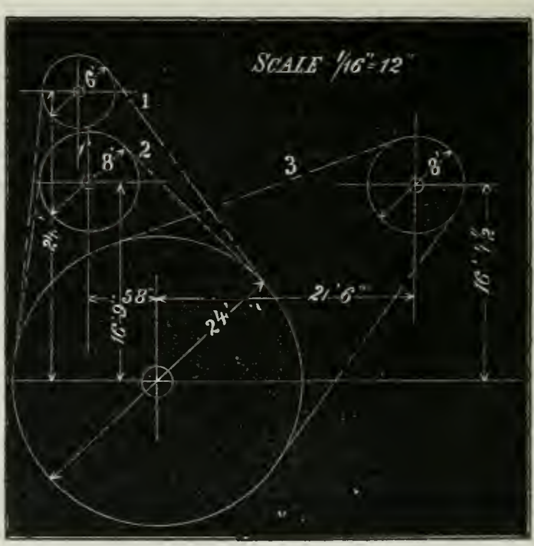
The belts transmit 250 horse power, have been in use since 1852, and are doing well. If we suppose each belt does half the work, we will have 33·64 square feet of belt in motion per minute per horse power.

Another case worthy of note is that of a 16 inch cylinder, 48 inch stroke horizontal Corliss engine, with 14 feet diameter fly wheel pulley, making 65 revolutions per minute, carrying a 12 inch double leather belt over a 5 feet pulley on the line shaft, which is located under the second floor of the factory in the usual way, and 17 feet horizontally distant from the engine shaft. This engine is doing 90 horse power, and has been running for 8 years. The velocity of belt surface here is 2860 feet per minute, and gives 31·77 square feet of belt per minute per horse power.

Mr. Spencer further says: "Whether a belt is more or less liable to slip on the larger pulley, I say less in all cases. There is great advantage in covering the smaller pulley with leather where much work is required. It is much better to use narrow belts and pulleys of large diameter than wide belts and pulleys of small diameter. This fact is probably less understood and appreciated than any other in connection with belts and pulleys. Belts require care in their application and management. I have belts that have been in use 22 years under rather unfavorable circumstances, and look to-day as if they would last 10 years longer.

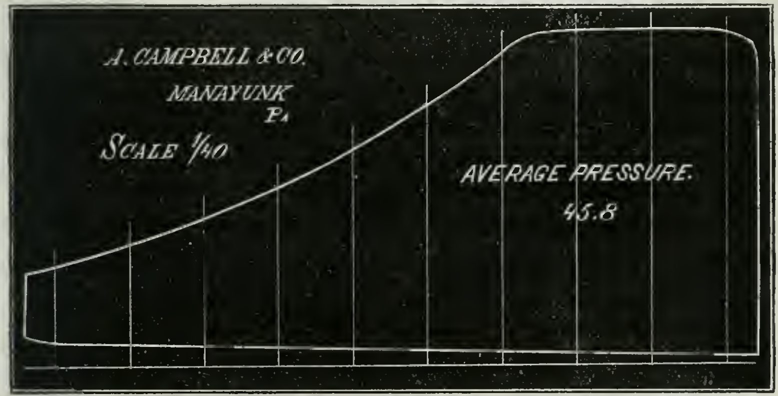
Mr. W. B. Le Van presents this and the next case of driving belts:

At A. Campbell & Co.'s factory, Manayunk, the motive power is transmitted by three belts to three separate line shafts, as shown below, (Fig. 3.)



Belt No. 1 to the upper 6 feet pulley is 17 inches wide. Belt No. 2 to the 8 feet pulley beneath, is $21\frac{1}{2}$ inches wide. Belt No. 3 to the 8 feet pulley, to the right in the cut, is $26\frac{1}{2}$ inches wide. The belts are all double leather, and run from the pulley fly-wheel on the engine-shaft, which is 24 feet diameter, 6 feet width of face, and weighs, with its shaft 43 tons. The engine is a horizontal Corliss, with 30 inch cylinder, 5 feet stroke, making 52 revolutions per minute, driving about 20,000 spindles and the usual connected machinery.

Below (Fig. 4) we give an Indicator card taken from engine on March 2d, 1874, under a boiler pressure of 85 lbs. Scale of card 30 lbs. to the inch, average pressure 45·8 lbs., horse-power exerted by one pound of pressure 11·14, estimated power to run engine only 16·71; hence we have (11·14 × 45·8) — 16·71 = 493·5 horse-power. Some of the cards ran as high as 47 lbs. average pressure. The average of 8 cards was 456·74 horse-power.



At Great Bend, Indiana, an 18 inch cylinder, 48 inch stroke, Corliss engine, under 90 lbs. of steam, at 65 revolutions per minute, transmits 190 horse-power usually, and at times 222 horse-power, through the medium of a 22 inch single leather belt over a 12 foot fly-wheel pulley to a 42 inch pulley on the line shaft.

This belt was originally 24 inches wide, but using the figures above we get 23·64 and 20·23 square feet of belt in motion per minute per horse-power, respectively. This is the hardest worked belt of any yet noted.

A single leather belt in good driving condition has been frequently used in testing car wheel forcing presses. Under the following conditions this belt was repeatedly found to do the work. Belt 6 inches wide, pulley 24 inches diameter, of iron smooth turned, crank 2 inches radius, plunger 15-16ths inch diameter in an $1\frac{1}{4}$ inch barrel, hydraulic pressure 7000 pounds per square inch; hence we have:

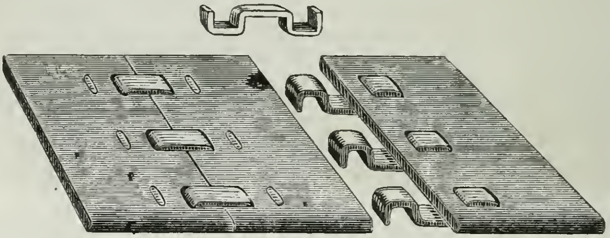
$$\frac{(\text{area of } 1\tfrac{1}{4} \text{ inches} - \text{area of } 15\text{-}16\text{ths})\ 7000}{6 \times 6} = 104{\cdot}36.$$

From this we may safely conclude the maximum driving force of a single leather belt to be near 100 lbs. per inch of width.

From Leigh's *Science of Modern Cotton Spinning*, 1873, we copy the following rule for double leather belts: "Multiply the square inches of belt contact on the smaller pulley by half the speed of the belt in feet per minute and divide by 33,000. The quotient gives the horse-power to which the belt is equal."

This rule provides for twice the quantity of belt needed, as shown by the examples from actual practice quoted above.

Largest English Belt. — "A leather belt, said to be the largest ever made in this country, is now being exhibited at 20 Market-place, Manchester, by the maker, Mr. W. T. Edwards. It is made of English leather 36 inches in width, and is 83 feet long, in two thicknesses, and without a cross joint in the whole length. The belt has been made for Messrs. Witham Brothers, cotton spinners, of Burnley, to transmit 300 horse-power off a drum 16 feet diameter."—*Engineering*, *March* 27, 1874.



Champion Belt Hook.—The above cut (Fig. 5) will convey a correct idea of the manner of adjusting this hook. It will be observed that the substantial double bearing of each hook precludes the possibility of its "tearing out." Shortening or taking up slack in belts is only the work of a moment, when this hook is used. It is conceded that no belt fastening is equal to this for strength. It is less expensive than the *Blake stud*, or than *lace leather*, and although it costs more than the "C" hook, it is in the end cheaper, because it retains its original shape in the belt, and the same hook can be used over and over again. It can be adjusted with greater ease and in much less time than any other belt fastening.

Tests of Shafting by SAMUEL WEBBER, C. E., Manchester, N. H., 1874.

DATE.	PLACE.	Length.	Diameter.	Weight.	Weight of Pulleys.	Total Weight.	No. of Bear'gs.	Rev. per Minute.	Ft. Lbs.	Horse-Power.	Coeff. Friction.	REMARKS.
												CONTINUOUS OILING.
April, 1871	Amoskeag Mills,	8 ft. 6 in.	2⅛ inc.	101 lb.	577 lb.	678 lb.	2	216	49	·089	·0336	Single Counter. Dreyfuss Pat. Oiler. Sperm and Kerosene Oils mixed.
“	“	34	“	404	1,974	2,378	8	216	196	·357	·0413	4 Count's like above. Connected with Belts. Same Oils mixed.
“	“	114	“	1,366	1,859	3,225	15	216	325	·590	·0500	Single line. Oilers as above.
“	“	228	“	2,732	3,617	6,349	30	216	650	1·181	·0501	2 Lines like above connected. Oils, etc., same.
“	“	342	“	4,098	5,331	9,429	47	216	1,022	1·858	·0552	3 “ “ “ “ “
“	“	16	2⅝ inc.	2,427	2,988	5,415	25	216	378	·687	·0338	Single line, “ “
“	“	178	2⅛ “									
“	“	10 ft. 4 in.	4⅛ “	3,910	5,393	9,303	26	210	873	1·587	·0334	Single line, Oils, etc,, same.
“	“	80	2⅞ “									
“	“	32	2⅝ “									
“	“	48	2⅜ “									
“	“	32	2⅛ “									
												ORDINARY OILING.
July, 1871	“	10	2⅝ “	1,289	1,456	2,745	12	150	275	·499	·0640	Single line. Oiled in ordinary way, daily. Tallow in Boxes, as safeguard in case of Heating.
“	“	48	2⅜ “									
“	“	32	2⅛ “									
“	“	Similar line			1,006	2,295	12	150	217	·394	·0610	“ “ “ “
“	“	34	2⅝ “	1,484	1,736	3,220	13	150	291	·537	·059	“ “ “ “
“	“	32	2⅜ “									
“	“	32	2⅛ “									
“	“	10 ft. 4 in.	2⅞ “	2,336	2,999	5,335	24	211	793	1·442	·0759	Single line. Had been oiled A. M., test at 11 A. M.
“	“	176	2⅛ “									
“	“	Similar line		2,336	2,999	5,335	24	211	679	1·234	0·650	“ “ Taken just after oiling.
Jan., 1872	Whittenton Mills	About 200 ft.	2¼ “	2,700*	.....	.....	....	155	314	·571	.....	
Feb., 1872	Langdon “	24 ft. 10 in.	2⅛ “	295	350	645	4	210	143	·260	·114	“ “ Sprung in centre by pull of Belt.
Mar., 1872	Haydensville,	42	2⅛ “	428	.....	.....	5	120	147	·267	·....	
April 1, '72	Salmon Falls, N. H.,	9	4 “	3,151	2,354	5,805	31	211	857	1·558	·0714	“ “ Tallow in Boxes, taken at noon; had been oiled early in A. M.
		231	2⅛ “									
April 2, '72	“	Same shaft.		3,151	2,354	5,805	31	211	619	1·120	·0516	Tallow removed from Boxes, and sponge saturated in oil substituted. Time of testing as before.
May, 1872.	Rockport, Mass.	9 ft. 10 in.	3 “	1,987	2,000*	3,987	30	185	376	·685	·0568	Oiled daily in usual manner.
	“	32	2⅜ “									
	“	32	2⅛ “									
		96	1⅞ “									
May, 1872.	Masconom't M'l Newburyport,	10 ft. 8 in.	3 “	3,554	4,268	7,882	37	245	1,028	1·870	·0585	“ “ “ “
		24	2½ “									
		127 ft. 1 in.	2¼ “									
		64	2 “									
		64 ft. 3 in.	1¾ “									
Nov., 1872.	Paterson, N. J.,	100	1⅝ “	unkn'wn	unkn'wn	unkn'wn	11	170	184	·335	.....	Dreyfuss Oilers.
Nov., 1873.	Granite Mills, Fall River.	About 200 ft.	2 “	“	“	“	....	200	302	·549	.....	“ “

*Estimated.

AN ACCOUNT OF AN EXPLOSION OF A LOCOMOTIVE BOILER.

By Chief Engineer B. F. Isherwood, U. S. Navy.

In January, 1873, the boiler of a locomotive belonging to the "North Pennsylvania Railroad" exploded while the engine stood at the depot awaiting the time to start with a train.

This boiler was constructed of excellent material and workmanship by the "Baldwin Locomotive Works," in January, 1869, and was, consequently, about four years old. Its cylindrical shell was 4 feet in diameter, and composed of 5-16ths of an inch thick steel plates, the longitudinal seams only of which were double-riveted with $\frac{5}{8}$ths of an inch diameter rivets, the cross seams being single-riveted. The length of the fire-box—measured to the tube-plate—was 11 feet, and its breadth was 2 feet and 10 inches. The cylindrical shell contained one hundred and thirty-six tubes of $1\frac{1}{2}$ inch diameter.

At the moment of the explosion, the boiler was well filled with water; its steam-gauge showed a pressure of 100 pounds per square inch above the atmosphere, and the blower was in operation to increase that pressure to 120 pounds before starting. The fireman, who was watching the gauge in order to stop the blower as soon as the latter pressure was attained, escaped uninjured; but the engineer, who was standing by the side of the locomotive, oiling its machinery, was thrown down by the explosion and remained for some time insensible, receiving, however, no permanent injury.

The rupture took place near the middle of the cylindrical shell, and in one plate only, which was fractured through the solid metal successively on opposite sides of the shell and a little below the horizontal plane passing through its axis.

These fractures were nearly in straight lines horizontally, and the two edges of the remaining part of the broken plate were bent over outwards. On both sides of the shell, the fractures extended the whole length of the plate up to the two cross seams, one at each end, which united it to the adjacent plates. These cross seams were also ruptured, but only above the horizontal fractures, and must have given way in the interval of time between the two longitudinal fracturings, and their yielding was partly through the solid metal of the plate, partly through the line of rivet holes, and partly through the shorn rivets. The portion of the plate thus blown out had the shape originally of a vault whose cross section was a little more than a semicircle of 4 feet in diameter, and whose length was the distance between the two cross seams, one at each end, joining it longitudinally to the adjacent plates: if flattened, this vault-shaped piece would have formed nearly a perfect parallelogram. It was hurled by the explosion about 400 feet horizontally and with such violence that it passed first through the front and rear walls of a brick house about 200 feet distant, and then through a brick wall situate about 200 feet further on. The entire front of the house was daubed and stained with the muddy water of the boiler. The feed-pipe, which was attached to the ruptured plate at one of its horizontal lines of rupture, was broken off and thrown in an opposite direction, killing a man and boy who were standing about 250 feet from the boiler. The steam-pipe (about 6 inches diameter) and all the tubes except those of the two lower rows, were completely collapsed, torn from their plates, and bent or bowed out toward the opening made by the explosion, but not ejected from the shell. The tubes of the two lower rows remained intact; the locomotive stood unmoved on the rails, and no other portions of it were injured in the least degree than those above mentioned.

At the lines of longitudinal fracture, the plate was found to have been cracked along its whole length, previously to the explosion, to the depth of 4-16ths of an inch, leaving only 1-16th of an inch of solid metal to sustain the pressure of the steam, instead of the 5-16ths of an inch that the plate possessed at all other parts. Thus the pressure in the boiler of 100 pounds of steam per square inch, was opposed by 1-16th of an inch thickness of metal on each side, or ⅛th of an inch in the aggregate, making the strain on the metal per square inch of its section ($\frac{48 \times 100 \times 1}{0.125 \times 1} =$) 38,400 pounds supposing no assistance to have been derived from the riveting of the ruptured plate to the adjacent ones; and less than that to the extent of any such assistance.

All the facts of this explosion are well ascertained. They are:—

1st. The exploding steam-pressure was 100 pounds per square inch above the atmosphere, up to which it had been gradually raised.

2d. The boiler was well filled with water.

3d. The locomotive was standing motionless on the rails.

4th. One of the plates of the cylindrical shell was cracked horizontally along its whole length and on both sides of the shell, reducing the original thickness of the metal, at nearly diametrically opposite sides of the shell, four-fifths. The plate had apparently been in this state for a considerable time before the explosion.

5th. Under these conditions fracture occurred along the two cracks, and, at right angles to them, along that part of the two cross seams lying above the cracks. These cross seams joined the cracked plate to the adjacent ones. The broken out piece of plate being the upper half of the cylindrical shell for the length of the fractured plate, formed, when flattened, nearly a perfect parallelogram. The fracture along the cross seams, was partly through the full thickness of the plate, partly through the line of the centres of the rivet-holes, and partly through the shorn off rivets.

6th. Nearly all of the water together with its contained mud, was projected from the boiler and thrown to a considerable height, scattering widely right and left as it fell.

7th. The broken out piece of plate was thrown at a small angle above the horizon; and both the horizontal edges of the remaining part of the plate were curved over and outwards.

8th. The steam-pipe, and all the tubes with the exception of those of the two lower rows, were collapsed, torn from their plates and bowed toward the large opening made in the top of the shell by the explosion, but none were thrown out of the shell.

9th. No damage other than what has been described, was done by the explosion to the locomotive, which remained throughout motionless upon the rails.

10th. The metal yielded under a tensile strain of only about 38,400 pounds per square inch of its section.

It is probable that the shell first gave way at one of the cracks and along the whole length of the cracked plate; that the broken out piece of metal was then torn or rather shorn along the two cross seams, flattening as it proceeded, until the crack on the opposite side of the shell was reached, when the metal there gave way under the combined tensile and transverse strains brought upon it, and the detached piece was hurled with great violence in a direction slightly inclined above the horizon.

Through the opening thus made in the top of the shell, nearly all the water in the boiler was projected to a considerable distance, and with such force as to collapse the tubes, tear them from their plates, and bend them in the direction of the opening, but not with sufficient force to drive them through that opening. This water spreading as it left the boiler, probably beat out or curved over the two horizontal edges of the remaining portions of the fractured plate.

This explosion is an illustration of what occurs in a boiler containing water and a rapidly but continuously increasing steam-pressure when a large portion of its shell is so weakened by cracks nearly through the plate and of such form as to enclose a piece of metal which may be considered as a very large *unweighted* safety-valve *stuck* to its seat and, consequently yielding *suddenly* and *completely* when the pressure rises sufficiently to overcome the sticking. The difference between this case and that of a safety-valve consists in this: that the latter is *weighted*, and the cracked-around piece of the metal is *unweighted*. The safety-valve opens when the pressure to which it is weighted is attained, and permits the gradual escape of any steam additionally generated, but retains the pressure for which it was weighted within the boiler, consequently, any projection of water from the boiler is impossible, because the constant pressure maintained upon the water is that which is normal to its temperature; but, if the safety-valve be supposed unweighted, and held in its seat only by adhesion, then, when the pressure rises sufficiently to overcome that adhesion, the valve will be blown from its seat with great velocity, and the opening, if large enough, so produced in the shell will discharge all the steam at once, reducing the pressure to that of the atmosphere, while the water having the temperature normal to the pressure of the steam before its sudden discharge, will, under the reduced pressure, be set into violent ebullition and projected with great force along with and by the steam thus simultaneously generated throughout its entire mass. This would be an exact reproduction of the phenomena of the explosion above narrated, with an opening of the size of that in the exploded boiler, and with an equal steam-pressure. It shows that a true explosion with much destruction may result from a boiler having a weak spot, if this spot be sufficiently large, while all other parts have ample strength, instead of a mere rupture at this weak spot accompanied by a harmless discharge of steam as in the case of a safety-valve. Of course, the destructive effect will be in proportion to the pressure of the steam at the moment of the explosion.

It is probable that the metal was not ruptured wholly by the tensile strain of 38,400 pounds per square inch of section, but was cracked a few moments before the explosion still more deeply than the quarter of an inch shown at the blackened edges, and which was evidently of long standing, by buckling under the rapidly changing temperature due to the rapidly increasing steam-pressure, an effect to which a brittle material like steel is always liable.

[Entered according to act of Congress, in the year 1873, by John Richards, in the office of the Librarian of Congress at Washington.]

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

[Continued from Vol. lxviii, page 206.]

Aside from the greater rapidity with which a hammer may operate when working on this principle, there is nothing gained and much lost; and as this kind of action is imperative in any hammer that has a "maintained connection" between its reciprocating parts and the valve, it is perhaps fair to infer that the reason why most automatic hammers act with an elastic blow is either from a want of knowledge as to a proper valve arrangement, or because of mechanical difficulties in arranging valve gear.

In working with dead blows no steam is admitted under the piston until the hammer has finished its down stroke, and expended its momentum upon the work. So different is the effect of these two plans of operating, that on most kinds of work a fifty pound hammer working with dead blows, will perform the same duty that one of a hundred pounds will, when acting with elastic or cushioned blows.

This difference between the dead and elastic stroke is so important that it has served to keep the hand moved valves in use in many cases where much could be gained by automatic hammers that had the same functions.

Some of the makers of steam hammers have now so perfected the automatic class, that they may be instantly changed so as to work with either the dead blow or the elastic blow at pleasure, thereby combining all the advantages of both principles. This brings the steam hammer where it is hard to imagine a want of farther improvement.

The valve gear of automatic steam hammers to fill the two conditions of allowing a dead or an elastic blow, furnishes one of the most interesting examples of mechanical combination.

It was stated that to give a dead or stamp stroke, the valve must move and admit steam beneath the piston after the hammer has made the blow, and stopped on the work, and that such a movement of the valve could not be imparted by any maintained connection between the hammer-head and valve. This problem is met by connecting the drop or hammer-head with mechanism that will by reason of its momentum, continue to "move after the hammer-head stops." This mechanism may consist of various devices. Messrs. Massey in England, and Messrs. Ferris & Miles in America, employ a swinging wiper bar that is by reason of its weight or inertia, retarded and does not follow the head closely on the down stroke, but swings into contact and opens the valve after the hammer has come to a full stop.

By holding this wiper bar continuously in contact with the hammer drop, elastic or rebounding blows are given, and by adding weight in certain positions to the wiper bar, its motion is so retarded that the hammer will act as a stamp or drop. A German firm employs the concussion of the blow to disengage the valve gear, and effect this after movement of the valves in steam hammers. Other makers effect the same end by employing the momentum of the valve itself, by having it connected to the drop by a slotted or yielding connection, that allows an independent movement of the valve to a certain extent.

COMPOUND HAMMERS.

Another principle to be noticed in connection with hammer action in forging processes is that of the inertia of the piece operated upon, a matter of no little importance in the heavier class of work.

When a piece is placed on an anvil and struck on the top side with a force of one ton, the bottom or anvil side of the piece does not receive an equal force. A share of the blow is absorbed by the inertia of the piece, and the effect on the bottom side is, theoretically, directly as the force of the blow, less the inertia of the pieces acted upon.

In practice this difference of effect on the top and the bottom, or between the anvil and the hammer sides of the iron, is much greater than would be supposed. The yielding of the soft metal on the top cushions the blow and protects the under side from the force; this, because the effect produced in striking a piece of heated iron is by no means to be measured by the force of the blow. It requires, to use a technical term, a certain amount of force to "start" the iron, and anything less than this force has but little effect in starting the particles and changing the form of the piece.

From this the apprentice can see that there must occur a great loss of power, for whatever force is absorbed by the weight of the piece produces no effect. By watching a smith using a hand hammer it will be seen that whenever the piece operated upon is heavier than the hammer, but little if any effect is produced on the anvil or bottom surface. Nor is this loss of effect the only one. The cost of heating, which generally exceeds the cost of shaping, is directly as the amount of shaping that may be done at each heat; and consequently if the two sides of a piece, instead of one, can be equally acted upon in shaping, one-half the heating will be saved.

Another consideration to be gained by equal action on both sides of large pieces is the quality of the forgings produced, which is generally improved both by the rapidity of the shaping processes, and injured by too frequent heating.

This loss of effect by the inertia of the piece acted upon being as the relative weight of the hammer and the piece, it follows that the loss increases with the weight of the work; not only the loss of power, but the cost of heating, which also increases with the size of the work. There is such a difference in the mechanical conditions between light and heavy forging that for any but heavy work there would be more lost than gained in attempting to evade or remedy this loss of effect on the anvil face of the work.

To remedy this defect in heavy forging, Mr. Ramsbottom, C. E., designed what I have termed compound hammers, consisting of two independent heads or rams moving in opposite directions, and acting simultaneously upon the work which is held between them.

These hammers of Mr. Ramsbottom were a departure from all modes of forging that had ever been practiced to the time, and constituted an original invention; one that has fully attested its value in actual service at Crewe, England, where such hammers have been at work for several years.

It will seem probable that the arrangement of these double acting hammers is necessarily complicated and expensive, but the contrary is the fact. The rams are simply two masses of iron mounted on wheels that run on tracks like a truck, and the impact of each hammer, so far as not absorbed in the work, is neutralized by the other. No shock or jar is communicated to framing or foundations as in the case of single acting hammers that have fixed anvils. The same rule applies in the back stroke of the hammers, as the links that move them are connected together at the centre, where the power is applied at right angles to the line of the hammer movement. The links connecting the two hammers constitutes, in effect, a toggle joint, the steam piston being attached when the links meet in the centre.

The steam cylinder is set at some depth in the earth below the plane upon which the hammers move, and even when the heaviest work is done there is no perceptible jar to be felt when standing near the hammers, as there always is with those that have vertical movement and are single acting.

The apprentice is recommended to procure and study drawings of these hammers as a most interesting example of modern engineering practice.

As drops bear a close analogy to steam hammers and press forging, not used to any extent in machine shops, it will hardly be worth while to devote any space to forging machinery of this class. The purpose being to treat of what the apprentice will meet in the smith's shop and to confine explanation so far as possible to what is in common use.

TEMPERING STEEL.

Tempering is the romance of the smith's shop, it has an attraction about it that characterizes every process that is mysterious, especially any process connected with, or belonging to mechanical manipulation. A strange and perhaps fortunate habit of mind is to be greatly interested in what is not understood, and to disregard what is capable of plain demonstration.

An old smith who has stood at the forge for a score of years, will take almost the same interest in tempering processes that a novice will. Give an old smith a piece to temper that is liable to spring or break when the risk is great, and he will enter upon it with the same zeal and interest that he would have done when learning his trade.

No one has been able to explain why a sudden change of temperature hardens steel, nor why it assumes various shades of color at different degrees of hardness; even the most critical researches into the chemistry of steel has offered no rational explanation. We only know the fact, and that fortunately steel has such properties. Every one that uses tools should understand tempering them, whether it be for iron or wood work. Experiments with tempered tools is the only means of determining the proper degree of hardness, and as smiths except with their own tools have to rely upon the explanations of others as to proper hardening, it follows that tempering is generally a source of complaint with those who use tools hardened by others.

Tempering, which as a term, is used to comprehend both hardening and drawing, is almost solely a matter of judgment, instead of skill, and has no such intimate connection with forging as to be performed by smiths alone. In fact it requires a different kind of fire from those used in forging, and also requires as a process more care and precision than blacksmiths usually exercise in their operations, unless they have furnaces and baths especially arranged for tempering tools.

A difficulty that arises in hardening is from the contraction of the steel which takes place in proportion to the change of temperature; and as the time of cooling is in proportion to the section of a piece, it follows of course, that there is a great strain and a tendency to break the thinner parts before the larger parts have time to cool and contract, or this strain may take place from the cooling of one side first, or more rapidly than another.

The following propositions in regard to tempering, comprehend the main principles to be observed:

The permanent contraction of the steel is as the degree of hardness that is imparted to it by the bath.

The time in which the contraction takes place is as the cross section of the piece at any part; or in other words the heat passes off first from the surface, and then uniformly from the surface to the centre.

The thin sections of steel tools being removed from or projecting from the mass which supports the edges are cooled first, and if provision is not made to allow for contraction, the thin sections or edges are torn asunder.

The main point in hardening and the most that can be done to avoid irregular contraction, is to apply the bath so that it will act first and strongest on the thickest part. If a piece is tapering or in the form of a wedge, the thick end should enter the bath first; a cold chisel for instance that is wide enough to endanger cracking should be put into the bath with the head downward.

The upflow of currents of warmed water are a common cause of irregular cooling and the springing of steel tools in hardening; the water that is heated, rises vertically, and the least inclination of a piece from a perpendicular position, allows this warm current to flow up on one side and to leave the piece on the other.

The most effectual means of securing uniform effect from the bath is by violent agitation, either of the bath or the piece; this also adds to the rapidity of the cooling.

The effect of tempering baths is as their conducting power; chemical effect need not be considered except as it may contribute to this.

For baths, cold water or ice water loaded with salt and warm oil, are the two extremes outside of which nothing is required.

In tools composed partly of iron and partly of steel, steel laid as it is called, the tendency to crack in hardening may be avoided in a great degree by hammer-stretching, hammering the steel edge at a low temperature until it is expanded so that when cooled in hardening it will only contract to a state of rest with regard to the iron parts; the same effect can be produced by curving a piece, giving convexity to the steel side before hardening.

Tools should never be tempered by immersing their edges or cutting parts in the bath, and then allowing the heat to "run down" to do the tempering. I am well aware that this is attacking a general custom, but it is none the less wrong for that reason.

Tools so hardened have a gradually diminishing temper from their point or edge, so that no part is properly tempered, and they require continual re-hardening, which spoils the steel; besides the extreme edge is usually spoiled and must be ground away to begin with. No latheman who has once had a set of tools tempered throughout by slow drawing, either in an oven, or on a hot plate, will ever consent to point hardening afterwards. A plate of iron, two to two and one-half inches thick, placed over the top of a tool dressing fire, makes a convenient place for drawing temper, besides adding greatly to the convenience of slow heating, which is almost as important as slow drawing. The writer has in one case by actual experiment determined that the amount of tool dressing and tempering, to say nothing of time wasted, was in ordinary machine fitting, reduced more than one-third by "oven tempering," the tools for lathes and planing machines.

As to the shades that appear in drawing temper, or tempering it is sometimes called, it is quite useless to repeat any of the old rules about "steam color, violet, orange, blue," and so on, the learner knows as much after such instruction as before. The shades of temper must be seen to be learned, and as no one is likely to have use for the knowledge before having opportunities to see tempering done, I will recommend the following plan which will be found an efficient one to begin with, in learning the shades of temper: Procure 18 pieces of cast steel about two inches long by one inch wide and three-eighths of an inch thick, heat them to a high red heat and drop them into a salt bath, leave one without tempering to show the white shade of extreme hardness, and grind off and polish one side of each of the remaining seven pieces; then give them to an experienced tool maker to be drawn to seven various shades of temper ranging from the white piece to the dark blue color of the soft steel. On the backs of these pieces paste labels describing the technical name of the shades and the general uses to which tools of corresponding hardness are adapted.

This will form an interesting collection of specimens, and accustom the eye to the various tints, which will after some experience be instantly recognized when seen separately.

It may be remarked as a general rule the hardness of cutting tools is "inversely as the hardness of the material to be cut," which seems anomalous and no doubt is so if nothing but the edge is to be considered; but all edges are subjected to transverse strain and this transverse strain is constantly as the hardness of the material acted upon; hence the degree of temper has of necessity to be such as to guard against breaking. Tools for cutting wood for example can be much harder than for cutting iron, or to state it better, tools for cutting wood are harder than those usually employed for cutting iron, for if iron tools were always as carefully formed and as carefully used as wood tools are, they could and should be equally hard.

Forges, pneumatic operators for blast machinery for handling large pieces, and other details connected with forging, are easily understood from examples, and if treated of here would exclude other matters of greater interest to the apprentice.

FITTING AND FINISHING.

Fitting and finishing as a department of Engineering establishments is generally regarded as the main one.

These processes, being the final ones in constructing machinery, are more nearly in connection with its use and application, and besides consists in the organization, or bringing together the results of other processes, carried on in the drafting and pattern shops, the foundry and smith-shop.

To those who are unskilled, or who do not take a comprehensive view of engineering business as a whole, the finishing and fitting seems to constitute the whole of machine manufacture, an impression that the apprentices are especially to guard against, because nothing but a true understanding of the importance and relations of the different divisions of such can enable them to be thoroughly or easily learned.

In treating of finishing, therefore, the reader must consider it as one among several processes, as one out of at least four departments among which his attention is to be divided.

Finishing as a process is a secondary and not always an essential one; many parts of machinery are ready for use when they are forged or cast and do not require finishing; yet finishing must in many respects be considered the leading department of engineering establishments.

Plans, drawings and estimates are always based on the finished machinery; upon this result often it is organized, and when the parts have accurate dimensions; hence designs, drawings and estimates must first pass through the fitting shop and follow back to the foundry and smith shop, so that finishing, although the last process in the order of the work, is the first after drawing in every other sense; even pattern making which seems farthest removed from finishing, must be based upon the finishing dimensions, and to a great extent remodified by the conditions of fitting and finishing.

In casting and forging as preliminary operations the material is treated while in a heated and expanded condition. Besides the nature of these operations does not admit of testing dimensions with accuracy, so that forgings and castings require to be made enough larger than their finished dimensions to allow for irregularities and shrinkage.

Finishing as a process consists in cutting away this surplus material and giving accurate dimensions to the parts of machinery, when the material is at its natural temperature.

Finishing operations being performed as said upon material at its normal temperature permits handling, guaging and fitting together of the parts of machinery, and as nearly all other processes in converting metal involve heating, finishing may be termed the cold processes of metal work.

Finishing processes in metal work consist in cutting, abrading, and handling material. A proposition that may seem novel, yet these operations comprehend nearly all that is performed in a fitting shop.

Cutting processes may be divided into cylindrical cutting as in turning, boring, and drilling, to produce circular forms, plain cutting, as in planing, shaping, slotting and shearing, to produce plain or rectangular forms, and cutting to produce irregular outlines.

Abrading or grinding processes may be applied to forms of any kind.

To classify further—cutting machines may be divided into those wherein the tools move and the material is fixed, and those wherein the material is moved and the tool fixed, or, machines that involve a compound movement of both the tools and the material acted upon.

There is also the distinction between machine and hand cutting that may be noted. In the first the cutting is done in true geometrical lines, the tools or material being moved by positive guides as in planing and turning; in hand operations, such as filing, scraping or chipping, the tools are moved without positive guidance, and act in irregular lines.

To attempt the generalization of the operations of the fitting shop in this manner may not strike the reader as a very practical means of understanding them, yet the application can be seen as we go farther on.

Tools directed to cutting include nearly all that are used in finishing operations, such as lathes, planing machines, drilling and boring machines, shaping, slotting and milling machines, and so on. These make up what is called standard tools, such as are essential and are found in all establishments where a full line of machine manufacture is carried on, and are constructed upon principles that are substantially the same in all countries at this day.

Besides these machine tools there are special machines to be found in most works, machines directed to the performance of some special work, where by a particular adaptation they are rendered more effective, but are, at the same time, unfitted for general use or to perform more than one function.

Engineering work cannot to any extent consist in the production of duplicate pieces, nor in operations that are constantly performed in the same manner as in ordinary manufacturing; hence there has been much effort expended in the adaptation of machines to general uses, machines that have not always avoided the objections of combining several functions in one, yet, upon the whole, machine tools may safely be regarded as the most perfect, and as having undergone the least change of any class of machines during twenty years past.

This general adaptation and certain standard forms of constructing machine tools enables their manufacture to be carried on as a regular branch.

The greatest improvement and change going on in machine fitting at the present time is in the adaptation of special tools. A lathe, a planing machine or drilling machine as standard machines must be adopted to a certain range of make, but it is evident that if such tools were specially arranged for either the largest or the smallest pieces that come within their capacity, more work could be performed in a given time and consequently done cheaper than on a standard machine; it is also considered that machine tools must be kept constantly at work in order to earn money, and when there are not sufficient pieces of one size to occupy a machine, the machine must do two or more sizes; but whenever there are sufficient pieces of a uniform size and certain processes of a uniform character to perform, there is a gain in having machines constructed to conform as nearly as possible to the requirements of special work, and without reference to any other.

This is in brief some of the principles that apply to special, as distinguished from general operations in machine fitting, and to which the attention of the apprentice is called as one of the important conditions connected with modern shop manipulations.

It is now proposed to review the standard tools of the fitting shop, the general principles of their construction and especially of their operation; not by drawings nor descriptions to show what a lathe or a planing machine is, nor how some particular tool builder has constructed them, but upon the plan explained in the introduction, presuming that the reader has seen and knows the names of standard machine tools, and has already learned such things at least as may be observed or understood by the unskilled.

If the reader has not learned this much and does not understand the names and general objects of the several operations carried on in the fitting shop, he should proceed to acquaint himself this far by personal observation and inquiries before troubling himself with books of any kind.

(To be continued.)

Chemistry, Physics, Technology, etc.

THE SPECTROSCOPE IN ITS APPLICATION TO MINT ASSAYING.

By Alexander E. Outerbridge, Jr.

The invention of the simple instrument called the Spectroscope has led, within a brief period of years, to such astounding revelations that it is not unnatural to imagine that untold possibilities may still lie concealed in its future. Those who are at all familiar with the subject of spectrum analysis, do not require to be told that the spectroscope has increased ten-fold the range of human knowledge within the domain to which it is applicable; and has also reduced much of what has heretofore been little better than matter of speculation, to a certainty as convincing, to a scientific mind, as a mathematical demonstration. Applicable alike to the analysis of tangible substances and of the celestial fires, its mysteries have been wrested from it, as it were, from an invisible world, by its devoted students.

All the classes of observations hitherto accomplished, fall under the head of *qualitative* analysis, in which perfection appears to have been already attained. Should a like perfection be attainable *quantitatively*, little more would appear desirable. With the view of probing for new facts in this direction, a limited but promising field of experiment has lately been adopted simultaneously, but independently, in the assay departments of the Royal Mint in England, and of the U. S. Mint at Philadelphia, and the attempt has been made to insert the wedge of future investigation by obtaining from the spectroscope a quantitative analysis of the composition of metallic alloys.

In a late annual report of the Royal Mint, Mr. Wm. Chandler Roberts, the chemist of the Mint (who with Mr. J. Norman Lockyer, the pioneer in Spectroscopic research, has been conducting a series of experiments), states he is satisfied that by means of the Spectroscope very minute differences in composition of gold-copper alloys can be ascertained. He, however, "refrains from describing the process, as the exact method of manipulation had not been determined upon." In the following pages the attempt is made to narrate, not technically, the process adopted and the conclusion arrived at in the experiments made in Philadelphia, the details of which are contained in a report by the writer to the chief assayer of the Mint, dated May, 1874, and published in the Proceedings of the American Philosophical Society of the 15th of that month, Vol. xiv, page 162.

The beautiful party-colored band of light, resembling a section of a miniature rainbow, resulting from the passage of a ray of white light through a prism, is familiar to every one; this simple experiment forms an appropriate introduction to the fascinating study of Spectrum Analysis.

Every kind of light not strictly mono-chromatic may, by means of the prism, be resolved into its component colors. The Spectroscope is a simple combination of prisms and lenses for the scientific examination of these different colors or spectra.

The numerous terrestrial elements, when in the state of incandescent vapor, give their own distinctive colors, which appear in the Spectroscope as *lines of light* arranged in definite positions, whereby each element may be easily recognized.

The passage of powerful electric sparks (from an induction coil) between two terminal points of the metal to be examined, vaporizes a small portion of the metal, and this incandescent vapor transmits to the eye of the spectroscopic observer its *luminous autograph* which nature never counterfeits. Should either or both of the metallic points, or *electrodes*, consist of an alloy of two or more metals, the autograph of each may be clearly read.

Mr. Lockyer noticed, while studying these luminous autographs, that when he separated the metallic electrodes, causing the spark to leap a greater distance through the air, the spectral lines no longer continued to cross the entire field of vision but certain of them *broke in the middle*, and upon further increasing the distance between the electrodes, the hiatuses in the spectral lines increased proportionately, *but unequally with different alloys.* As the proportion of either metal of an alloy is increased, *its lines lengthen* and conversely with the lines of the other metal. Upon this discovery, Mr. Lockyer based the theory of a possible method of quantitative analysis.

The Spectroscope was known to be marvellously sensitive to the impression of these autographs, and it therefore appeared plain, that could such a method of analysis be reduced to a practical basis, its value would be immense in assaying metals used in coinage. For although the present modes of assaying precious metals have been brought to great perfection, yet the process is slow and tedious, requiring many chemical operations and great delicacy of manipulation; and "there is something captivating in the idea of a determination, as it were, by a flash of lightning or in the twinkling of an eye, what proportion of gold or silver is present in any bar or coin."

It was with the hope of reducing this beautiful theory of Mr. Lockyer to practice that these experiments were undertaken. The investigation extended over a period of several months, the principal part of the work being conducted at the University of Pennsylvania, with the benefit of the excellent apparatus and appliances afforded in the new college building: a privilege kindly extended by Professor Barker of that institution.

A powerful induction coil, reinforced by Leyden jars, in connection with a two prism Browning spectroscope was employed, and it was found possible after repeated comparisons of the spectra of different known alloys of gold and copper to map the difference of fineness between specimens having respectively 500 and 750 parts of gold in 1,000 of the alloy, and even to recognize the variation between coin-ingots 895 and 902 fine. This variation, within seven thousandths, was by no means marked, although it seemed probable that a more delicate adjustment of apparatus and further experience would render the distinction more decided.

The spark, in passing through the air, also vaporizes its constituents, viz: oxygen, nitrogen, etc.; these of course write *their* signatures in the spectroscope, and it is necessary to eliminate the numerous bright air lines which thus appear in all the spectra. Some of the lines of different metals appear in close proximity and might readily be misinterpreted. Thus a bright blue line of bismuth is almost identical in position with one of zinc. A green line of iron is nearly coincident with a bright gold line. The difficulty which presented itself in the exact comparison of these proximate lines, was overcome by using a pure metal as one electrode and another pure metal as the other electrode. The effect thereby produced was very curious. With pure gold and pure copper as the electrodes, the gold lines extend across only one-half the field of the spectrum, and the copper lines extend across only the other half, the medial termini of both sets of lines being perfectly sharp and bright. By this means a double spectrum of copper and gold is obtained, or rather, a section of a complete gold spectrum and a section of a complete copper spectrum are visible in immediate juxtaposition, thereby enabling a most accurate comparison of lines, which in reality are not identical in position, but which by the previous method were apparently so.

By a slight modification of the experiment, substituting pure copper as one electrode and an alloy of silver and gold as the other, the proximate lines of these three metals are presented mapped, as it were, on a natural scale. (Fig. 1.)

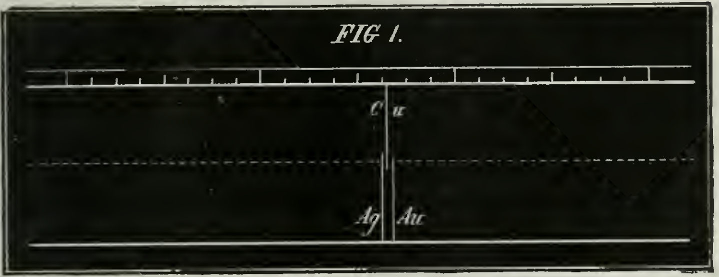


FIG 1.

Further modifications of this principle suggested themselves and were tried with indications of valuable results.

By using as one electrode, an alloy of gold and copper of comparative fineness, and a baser alloy of the same metals as the other electrode, a result not before observed presented itself. The lines of both copper and gold crossed the entire field of vision, but in the section representing the fine alloy, the gold lines were strong and bright, while in the section representing the base alloy the gold lines were very faint. (Fig. 2.)

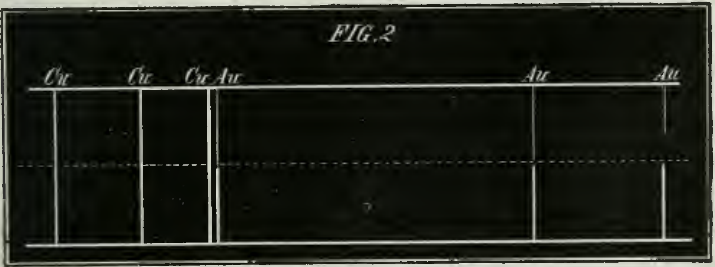


FIG. 2

By now gradually increasing the distance between the electrodes, the faint gold lines of the base alloy cease to join their bright counterparts of the fine metal at the central line. (Fig. 3.)

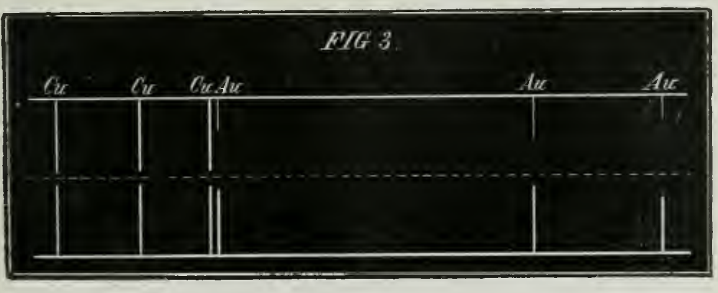


FIG 3.

The intervening space is at first minute, but as the electrodes are further separated, the ends of the faint lines gradually recede towards the outer edge of the spectrum, until they finally disappear altogether.

The general principle was thus satisfactorily proved, that where two alloys of different grades are subjected to this treatment, the gold lines of the baser compound are noticeably the fainter of the two, and what is more important, they may be reduced in length by separating the poles, until they disappear.

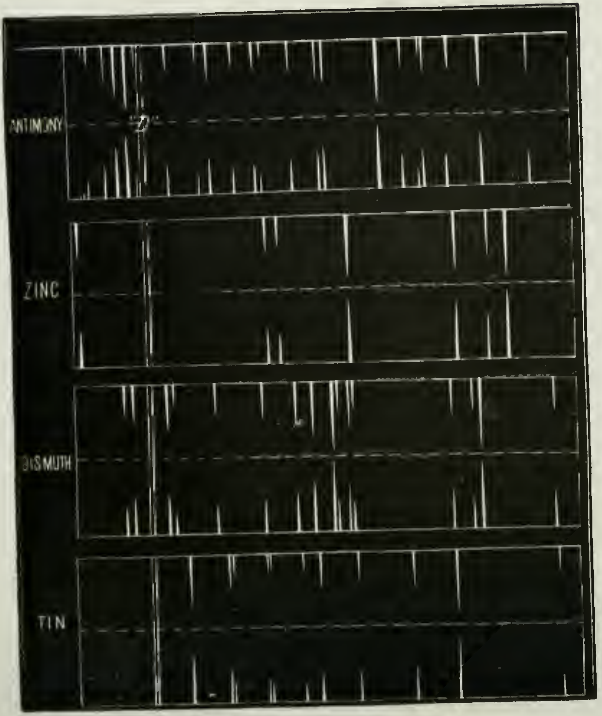
This pointed to the possibility of the future application of Spectrum Analysis to Assaying, at least as a test method. For, if an alloy of absolute known fineness were adopted as one electrode, and an ingot-slip assayed by the old process to an equal grade of fineness were inserted as the opposite electrode, in case the assay were correct, the gold lines in both sections of the spectrum should appear of equal brightness, and more especially, should begin to recede from the central line of the spectrum at the same moment, and should disappear at the same moment.

The spectra being inevitable natural effects of physical causes, a variation between two specimens of supposed equal fineness would, *in theory*, be necessarily indicated by the respective lines failing to correspond in their reciprocal action.

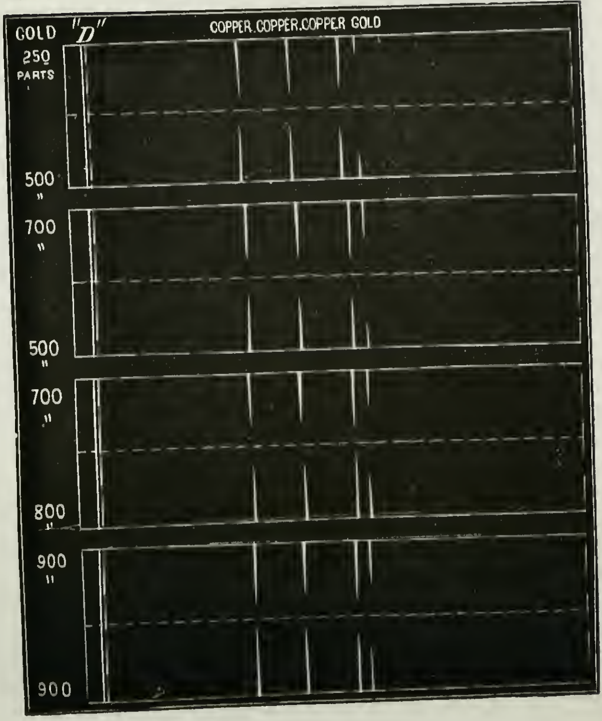
A serious source of error in these comparisons, was soon discovered, viz: that if one electrode was nearer the centre of the slit of the spectroscope than the other, its spectral lines would appear proportionately longer than those of its *vis-a-vis* even though both electrodes were of the same pure metal. It then became necessary to devise a special apparatus for manipulating the electrodes, when under examination. This was constructed by Mr. Samuel James, the machinist in the Mint, and admirably fulfilled its object. A wood-cut of it is appended hereto. Its peculiarity consisted in an automatic combination of accurately proportioned screws, acting in opposite directions, by which a single motion of the hand sufficed to cause the upper and lower electrodes to approach or recede from the central line of contact in an equal degree. The electrodes, which consisted of small strips of metal cut to a point, were held by a suitable arrangement on the outer circumference of two metallic rings insulated from each other, the upper one slotted to receive a series of twelve electrodes of varying *known* fineness, and revolving horizontally, so that each electrode might in turn be adjusted to face a single electrode of *unknown* fineness fixed on the lower ring. Its object was

PLATE 1

Spectra of Volatile Metals.



Quantitative Spectra of Gold-Copper Alloy.



to admit of the electrodes being separated to any desired extent, while preserving the line of vision, through the spectroscope, directed to the centre of the spark.

In regulating the height of the instrument, the apparatus was always adjusted by passing the spark between two electrodes of pure gold, so that, on separating the points, the respective spectral lines corresponded exactly in their reciprocal action.

A systematic series of experiments was now commenced, in which the behavior of the more volatile metals was at first studied, viz: Lead, Zinc, Bismuth, Tin, Antimony, Cadmium, Mercury, Aluminum, etc. All these give more decided spectra than the less volatile precious metals, and some interesting results were noticed. Approximate illustrations of some of these spectra are appended.

A very curious fact is apparent in all these spectra, viz: the *unequal lengths* of the spectral lines. Some of the lines of Bismuth, for example, are seen to extend nearly across the field of vision, while others appear as mere points upon the edge. Mr. Lockyer has published some most interesting investigations upon the subject of these "long and short lines."

Proceeding to the examination of gold alloys, and starting with base poles—making the lower pole 250 fine and the upper pole 500 fine—the gold lines from the upper half were both longer and brighter. Now substituting in place of the 250 pole one 700 fine, the lower half showed the brighter gold lines. Then, changing the 500 pole for one 800, the brightness of the gold line was again reversed. This alternating effect may be continued, decreasing in degree as the fineness of the poles approach more nearly together, until both poles are of the same fineness, when the lines will be equal in length and intensity.

These experiments proved satisfactorily that comparatively wide variations in the composition of gold alloys were discernible. A series of graduated alloys of more approximate fineness, was now prepared at the Mint, viz:

GOLD AND COPPER.	GOLD, SILVER AND COPPER.
938·	940·1
917·	918·7
906·	866·8
888·3	888·
883·5	884·1
876·5	883·

These alloys were carefully prepared and assayed closely.

With one electrode pure gold and the other 938 fine, the difference between the respective spectra was of course very marked, the copper lines appearing in the one and not in the other. Substituting for the pure gold the alloy 876·5, the difference was still very marked, for, although both gold and copper appeared in each, the copper lines were much brighter and somewhat longer in the baser alloy, while the gold lines were brighter and longer in the finer. But on comparing the alloys 876·5 and 883·5, (reducing the variation to seven thousandths) it was both a surprise and disappointment to find the visible difference of result but slightly appreciable. And the same with regard to the alloys of 883·5 and 888·3, and the same with other alloys with equal or less comparative variation of fineness. A variation of one-thousandth, required an effort of the imagination as well as of the eye to detect any difference whatever. And, although the attempt was made to map an apparent difference between alloys varying two-thousandths, it would certainly not have been a safe test on which to base an assay. Frequent repetitions with changes of adjustment were tried, the battery power varying from one to six Bunsen cells, in connection with Leyden jars varying from one very small jar (improvised out of a test-tube) to fifty large jars, representing a metallic superficies of many square feet) with variations of the distance of the electrodes apart, and with and without the use of a condensing lens, but all these failed to give closer results.

It is true, that these changes of conditions produced certain variations in the effects observed—as, for instance, it was noticed that an increase in the Leyden jar surface always lengthened the lines—the distance between the electrodes and all other conditions remaining the same—while a decrease in the condensing surface had an opposite effect. Thus, to take the extreme cases, with the single small Leyden jar above referred to, and one cell of battery, the lines broke when the electrodes were not more than one-sixteenth of an inch apart, and disappeared entirely on separating the points one-eighth of an inch.

With fifty Leyden jars and six cells of battery, it was found impossible to break the lines at all, even by removing the electrodes to the extreme limit of the spark, and in this case new lines also appeared.

Other variations occurred; such as a momentary irregularity in the length and brightness of the lines, under a strong battery power, owing to the unequal action of the spark;—a difference in the action of the gold lines dependent upon the nature of the alloy, silver tending to lengthen them more than equal admixture of copper;—the length of the lines is also dependent upon the distance between the spark and the slit (when the latter is used without the intervening condensing lens);—moreover, the eye itself is liable to become confused by continued comparisons of very slight differences. The above and other modifications, so far from solving the problem of close work, rather indicated possible sources of error.

Another element of the process suggested itself as likely to render the results uncertain for the practical purpose of assaying, viz: whether the quantity of metal vaporized and giving the spectrum is not too infinitesimal to give safe results for a large melt. This would be affected by the least want of homogeneity in the metal. This is a serious consideration, and with the view partly to search for unknown sources of error and partly to ascertain generally the quantity of metal operated on in a spectroscopic assay, (should that ever be possible) the following experiment was tried: Having weighed small electrodes, averaging 18 milligrammes each, with the greatest possible accuracy on the gold assay balance of the Mint, (which is sensitive to a twentieth of a milligramme, or even less,) and having arranged a spark register, it was found that 1000 sparks might be passed between these poles, each spark showing the spectrum of the metal distinctly, and yet the loss in weight was too small to be made the base of calculation. Thus, a gold pole lost in weight after passing 1000 sparks, one-thousandth of a grain; this gives for each spark 1-1000000th of a grain of gold, producing a bright spectrum. The number was then increased to 3000 sparks as a test. The loss of weight depends of course upon the electric volume, and in the experiments tabulated, an endeavor was made to keep the latter constant. A slight deposit of the vaporized metal from the opposite pole takes place in fine division, but this is easily removed—in the case of copper and gold poles by dipping the gold for a moment in weak acid, or by gentle rubbing. The annexed tables (marked A and B) show that the loss in weight is marvelously small, averaging less than seven-tenths of a milligramme of gold for 3000 sparks. To give the amount for each spark, this must be divided by the number of sparks; thus, in round numbers an electrode loses one-thousandth of a grain after passing 3000 sparks; or for 1000 sparks one three-thousandth of a grain, or for each spark 1-1000000th of a grain. The exceedingly small quantity of metal thus assayed renders this process, in the writer's opinion, inapplicable to the operations in the Mint; for it is necessary to determine gold assays to the one ten-thousandth part of the normal assay weight and it is hardly conceivable that a discrimination to the one ten-thousandth part of the spark assay weight, or the 1-1000000000th of a grain is practically possible. Even if it were, it would not be proper to assume that a test on such an atomic scale would correctly represent the value of a large deposit, or even of gold ingots. It would certainly not be in the case of silver, which segregates.

The experiments made by Cappel to determine the *minimum* amount of each element that will show a spectrum have been published in tabular form. His method was to volatilize "solutions of the metallic salts between the poles of a small induction coil in Mitscherlich's glass tubes with platinum wicks. A series of solutions, each one half the strength of the preceding one, were prepared from a number of metallic chlorides. The spectrum in connection with the positive pole was continually observed while increasingly concentrated solutions were brought in succession into the action of the spark until the lines of the substance were clearly visible." If a sceptical mind refuses to believe the results of Cappel, who tells us that one six hundredth of a milligramme (1-38800th of a grain) of nickel will *just* write the signature of that metal, what will he say when glancing at table B, appended hereto, he finds the statement that one sixty thousandth of a milligramme (1-3880000th of a grain) of nickel will sign its name *in brilliant characters?* And yet the author does not hesitate to say that even a *smaller* amount of this metal will show a spectrum, for it must be remembered that in these experiments a much stronger spark was used than was necessary to show a visible spectrum. When reduced to a minimum, as was done in the case of the miniature Leyden jar, which still gave a distinct spectrum, the loss in weight after 3000 sparks, for silver, copper and tin, was *absolutely inappreciable* on the balance.

The table of loss shows another curious and unexpected result, viz: that the loss in weight of the volatile metals very slightly exceeds and in some cases does not equal the loss of the less volatile metals. Thus, in three different experiments of 3000 sparks each, copper loses but ·1 mgr. while gold loses ·5 mgr.

An unexplained anomaly was also noticed in relation to the sensitiveness of the spectroscope to the metals present in small proportion. Although Mr. Cappel has shown that 1-4000th of a milligramme of gold will show a spectrum (it is even less than 1-6000th of a mgr. according to an experiment performed by the method described above) yet a comparatively large proportion of gold may be present in an *alloy*, the presence of which will not be indicated at all by the spectroscope.

In a slip composed thus: Silver, 708 parts; Copper, 254 parts; Gold, 38 parts; the spectra of *silver* and *copper* are alone visible.

In fact, in a base alloy of gold and copper containing from 20 to 25 per cent. of gold, the gold spectrum is barely visible; while in a fine alloy of gold and copper it was found that one per cent. of the latter suffices to show the copper spectrum. Also in an alloy of nickel and copper containing 25 per cent. of nickel its spectrum is scarcely visible. It seems evident therefore, that the spark selects the more volatile metal as its vehicle.

If the spectroscope fails to reveal the presence of anything less than 200 parts of gold in a base alloy, even a theorist must admit that one could scarcely expect to be able to discriminate with certainty a variation of 1-10000th in a fine alloy.

For the foregoing reasons, the conclusion seems inevitable, that in the state of spectroscopic science as it now exists, assaying by means of spectrum analysis is, for the present, impracticable for the purpose of Mint operations.

Although these experiments have resulted negatively from the utilitarian standpoint from which they were undertaken, it is hoped that they may prove not altogether without value in a more general point of view. The fact that quantitative proportions of composite substances may be recognized at all, even to a rough degree, cannot but be regarded as a first step. All observations bearing upon the action of the spectral lines in indicating such proportions are at least worthy of being recorded. Not the least curious of these incidental observations is the fact that while the Spectroscope is sensitive to the minutest fraction of a grain of gold in the pure state or in solution, it fails to reveal the presence of a much larger proportion in a base alloy. Another is the fact that while the spark appears to select for its vehicle of transmission the more volatile metal in an alloy and would thus seem to vaporize a greater quantity of the volatile than of the non-volatile component, yet in point of fact the loss of weight by such volatilization is in some instances much less in the former case than in the latter.

The rationale of these apparent paradoxes is not at present evident, but if we may judge by former experiences in which problems even more mysterious, have been resolved by study, we are warranted in anticipating that when a large number of observations, to be made perhaps by many experimenters groping in the dark, shall be collated, the true scent may of a sudden be struck which shall discover the desideratum of quantitative spectrum analysis.

TABLES.

The *first* column shows the weight of the metallic electrodes in milligrammes, before passing the sparks. *Second* column shows the weight after passing 3000 sparks. *Third* column shows the *total* weight of metal volatilized (in fractions of a milligramme). *Fourth* column shows the amount of metal volatilized by *each* spark (in fractions of a milligramme). *Fifth* column shows the amount of metal volatilized by each spark in fractions of a grain troy.

TABLE A.

	1		2	3	4	5
*Upper Pole	Gold	16·6	15·9	·7	1-4286	1-277000
Lower "	"	16·7	16	·7	"	"
Upper "	Copper	18·5	18·4	·1	1-30000	1-1940000
Lower "	"	"	"	·1	"	"
Upper "	Gold Ingot,	24	23·4	·6	1-5000	1-324000
Lower "	" "	"	"	·6	"	"
Upper "	Tin	20	19·6	·4	1-7500	1-486000
Lower "	"	"	19·4	·6	1-5000	1-324000
Upper "	Silver	24·8	24·6	·2	1-15000	1-976000
Lower "	"	25·1	25	·1	1-30000	1-1940000
†Average.	Lead	91·6	90	1·6	1-1870	1-121000

TABLE B.

Upper.	Gold	20·5	20	·5	1-6000	1-388000
Lower.	Copper	10	9·9	·1	1-30000	1-1940000
Upper.	Gold Ingot	21	20·4	·6	1-5000	1-324000
Lower.	Copper	20·2	20	·2	1-15000	1-976000
Upper.	Silver	6	5·8	·2	1-15000	"
Lower.	Tin	20	19·4	·6	1-5000	1-324000
‡Upper.	Nickel	12	11·95	.05	1-60000	1-3880000
Lower.	"	12	11·9	·1	1-30000	1-1940000

*The upper pole usually formed the positive electrode.

†The average of Lead is given because the results varied in different experiments.

‡The *minimum* of metallic Nickel producing a spectrum according to Cappel's tables is one six hundredth of a milligramme.

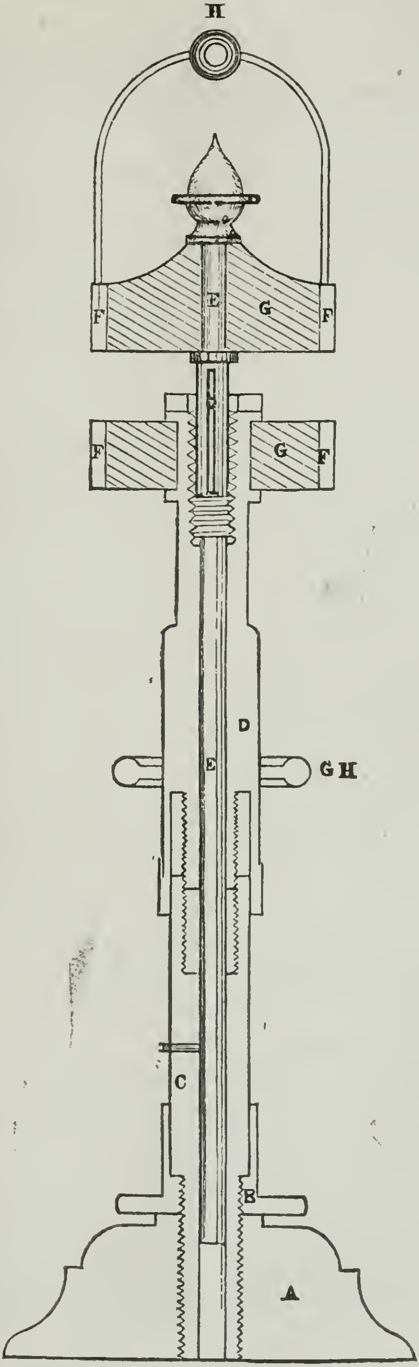


Fig. 4, Adjustable Rotary Stand for Spectroscopic Assay.

Chemistry, Physics, Technology, etc.

MECHANICAL SCIENCE.

An Address delivered before the Mechanical Section of the British Association at its meeting in Belfast, Sept., 1874.

BY PROFESSOR JAMES THOMSON, LL.D.

For a number of years past it has been customary in this and other sections of the British Association for the Advancement of Science, that the President should give an introductory address at the opening of each new session. In compliance with that usage, I propose now to offer to you a few brief remarks on various subjects of mechanical science and practice. These subjects have not been chosen on any systematic plan. I have not aimed at bringing under review the whole or any large number of the most important subjects at present worthy of special notice in engineering or in mechanics generally. I intend merely to speak of a few matters which have happened to come under my notice, or have engaged my attention, and which appear to me to be interesting through their novelty or through their important progress in recent times, or to merit attention as subjects in which amendment and future progress are to be desired.

In railway engineering, one of the most important topics for consideration, as it appears to me, is that which relates to the abatement of dangers in the conducting of the traffic. The traffic of many of our old railways has become enormously increased in recent years. With the construction of new lines the number of junctions, stations, and sidings has been greatly increased; and each of these entails some attendant dangers. As a natural consequence of the increased traffic on old railways, the additional traffic on new lines, and the increased complexity of the railway system as a whole, there have been during recent years more numerous accidents than in the earlier times of railways. It is to be recollected, however, that with a greater number of people traveling daily, more numerous accidents might be expected, and that their increased frequency, on the whole, does not necessarily indicate increased danger to the individual traveler. Referring to the statistics of railway accidents published by the Board of Trade in Capt. Tyler's Report for the year 1873, I find for various periods during the last twenty-seven years, throughout the United Kingdom, the proportion of passengers killed from all causes beyond their own control, to the number of passengers carried, to have been, in round numbers:—

Proportion of number killed to number carried:

In the three years 1847, 1848, and 1849, . .	1 in 4,782,000
In the four years, 1856, '57, '58, and '59, .	1 in 8,708,000
In the four years, 1866, '67, '68, and '69, .	1 in 12,941,000
In the three years, 1870, '71, and '72, . .	1 in 11,124,000
And in the single year 1873, ...	1 in 11,381,000

It is thus gratifying to observe, that in spite of the increased risks naturally tending to arise through the increased and more crowded traffic and the more complicated connections of lines, the danger to the individual traveler is now less than half what it was twenty-six years ago; at least this result is indicated, in so far as we can judge, from the statistics of deaths of passengers from causes beyond their own control. That the conducting of the traffic of railways still involves hazards far from inconsiderable, and that we have much to wish for towards abatement of dangers of numerous kinds, is proved by the fact that during the single year 1873 there have been killed of the officers and servants of the railway companies in the United Kingdom, 1 out of every 323; so that, at this rate, extended through a period of, for example, 20 years' service, there would be 1 out of every 16 of the officers and servants killed.

These deaths of officers and servants are not to be supposed to be caused in any large proportions by collisions, and by other accidents to trains in rapid motion.

The great majority of them arise in shunting and other operations at stations and along the lines, and occur in numerous ways not beyond the control of the individuals themselves. In respect to the passengers, too, it ought to be known and distinctly recollected, that although collisions and other violent accidents to trains in rapid motion, together with other accidents beyond the control of the individuals, usually cause by far the deepest impression on the public mind; yet the number of these fatal accidents is small in comparison with others arising to passengers from causes more or less within their own control. For instance it may be noticed that in last year, the year 1873, while the deaths of passengers arising from all causes beyond their own control, in the United Kingdom, were only 40 in number, there were four times as many killed, namely, 160, in other ways; and of these there were as many as 62 killed in the simple way of their falling between carriages and platforms.

In respect to the conducting of the traffic of the trains in motion, it appears to me, on the whole, than when we consider the vast complexity of the operations involved in working many of our ramified and crowded railways, and when we consider the indefinitely numerous things which must individually be in proper order for their duty, and must be properly worked in due harmony by men far away from one another, some stationed on the land, and others rushing along on the engines or trains, the wonder is, not that we should have numerous accidents, but that accidents should not be of far more frequent occurrence. There can be no doubt, however, but that of the accidents which do occur, many arise from causes of kinds more or less preventible according to the greater or less degree in which due precautions may be adopted.

Gradually, during a period of 20 or 30 years past, a very fine system of watching, signaling, and otherwise arranging for the safety of trains, has been contrived and very generally introduced along our principal lines of railway. In saying this I allude chiefly to the block system of working railways, with the aid of telegraphic signals and interlocking mechanisms for the working of the points and signals.

In former times it was customary to allow a certain number of minutes to elapse after a train passed any station, or junction, or level crossing, or other point where a servant of the company was stationed, before the succeeding train was allowed to pass the same place. Thus, at numerous points along the line a time interval was preserved between successive trains. It was quite possible, however, that the foremost of the two trains, after passing any of these places where the signals were given, might become disabled, or might otherwise be made to go slowly, and that the following train might overtake it, and come into violent collision with it from behind. In order to provide against the occurrence of such accidents, a system was introduced called the *Block System;* and its main principle consists in dividing the line into suitable lengths, each of which is called a *block section*, and allowing no engine or train to enter a block section until the previous engine or train has quitted that portion of the line. In this way a space interval of at least the length of a block section is preserved between the two trains at the moment of the later train's passing each place for signaling, and the risk of this space interval becoming dangerously small by negligence or other accidental circumstances, as the later train approaches the next place for signaling, is almost entirely avoided.

Further, at each signaling station, the various levers or handles for working the points, and those for working the semaphore signals for guiding the engine-drivers, instead of being, as was formerly the case, scattered about in various situations adjacent to the signaling station, and worked often, some by one man and some by another, without sufficient mutual understanding and without due harmony of action, are now usually all brought together into one apartment called the signal cabin. This cabin, like a watch-tower, is usually elevated considerably above the ground, and is formed with ample windows or glass sides, so as to afford good views of the railway to the man who works the levers for the semaphores and points, and who transmits, by electricity, signals to the next cabins on both sides of his own, and, when necessary, to other stations along the line of railway.

The interlocking of the mechanisms for working the points and for working the semaphores which, by the signals they show, control the engine-drivers, consists in having the levers by which the pointsman works these points and signals, so connected that the man in charge cannot, or scarcely can, put one into a position that would endanger a train, without his having previously the necessary danger signal or signals standing so as to warn the engine-driver against approaching too near to the place of danger.

The latest important step in the development and application of the block system is one which has just now been made in Scotland, on the Caledonian Railway. Before explaining its principle, I have first to mention that a semaphore arm raised to the horizontal position is the established danger-signal, or signal for debarring an engine-driver from going past the place where the signal is given. Now, the ordinary practice has been, and still is, to keep the semaphore arm down from that level position, and so to leave the line open for trains to pass, except when the line is blocked by a train or other source of danger on the block section in front of that semaphore, and only to raise the semaphore arm exceptionally as a signal of danger in front.

The new change, or improvement, now made on the Caledonian Railway consists mainly in arranging that along a line of railway the semaphore arms are to be regularly and ordinarily kept up in the horizontal position for prohibiting the passage of any train, and that each is only to be put down when an approaching train is, by an electric signal from the cabin behind, announced to the man in charge of that semaphore, as having entered on the block section behind, and when, further, that man has, by an electrical signal sent forward to the next cabin in advance, inquired whether the section in advance of his own cabin is clear, and has received in return an electrical signal meaning "*The line is clear: you may put down your debarring signal, and let the train pass your cabin.*" The main effect of this is, that along a line of railway the signals are to be regularly and ordinarily standing up in the debarring position against allowing any train to pass; but that just as each train approaches, and usually before it has come in sight, they go down almost as if by magic, and so open the way in front of the train, if the line is ascertained to be duly safe in front; and that immediately on the passage of the train they go up again, and by remaining up keep the road closed against any engine or train whose approach has not been duly announced in advance so as to be known at the first and second cabins in front of it, and kept closed, unless the entire block section between those two cabins is known to have been left clear by the last preceding engine or train having quitted it; and is sufficiently presumed not to have met with any other obstruction, by shunting of carriages or wagons, or by accident, or in any other way.

This new arrangement, which appears to be very important improvement, has already been brought into action with success on several sections of the Caledonian Railway; and it is being extended as rapidly as possible on the lines of the Caledonian Company, where the ordinary mode of working the block system has hitherto been adopted.

The mechanisms and arrangements I have now briefly mentioned are only a portion of the numerous contrivances in use for abatement of danger in railway traffic. It is to be understood that by no mechanisms whatever can perfect immunity from accidents be expected. The mechanisms are liable to break or to go wrong. They must be worked by men, and the men are liable to make mistakes or failures. We shall continue to have accidents; but, if we cannot do away with every danger, that is no reason why we should not abate as many dangers as we can.

Within the past twenty years very remarkable progress has been made in steam navigation generally, and more especially, I would say, in oceanic steam navigation. In this we meet with the realization of great practical results from the combination of improved mechanical appliances, and of physical processes depending on a more advanced knowledge of thermo-dynamic science.

The progress in oceanic steam navigation is due mainly to the introduction jointly of the screw propeller, the compound engine, steam jacketing of the cylinders, superheated steam, and the surface-condenser.

The screw propeller, in its original struggle for existence, when it came into competition with its more fully developed rival, the paddle-wheel, met with favoring circumstances in the want then strongly felt of means suitable for giving a small auxiliary steam-power to ships arranged for being chiefly propelled by sails. For the accomplishment of this end the paddle-wheel was ill suited; and so the screw propeller got a good beginning for use on long oceanic voyages. Afterwards, in the course of years, there followed a long series of new inventions and improved designs in the adaptation of the steam-engine for working advantageously with the new propeller; and it has resulted that now, instead of the screw being used as an auxiliary to the sails, the sails are more commonly provided as auxiliaries to the screw. For long oceanic voyages it became very important or essential to get better economy in the consumption of fuel. In order to economize fuel, high-pressure steam, with a high degree of expansion and with condensation, was necessary. This led to the practical adaptation for the propulsion of vessels of the compound engine, an old invention which originated with Hornblower in the latter part of the last century, and was afterwards further developed by Wolff. The high degrees of expansion could not be advantageously used in cylinders heated only by the ordinary supply of steam admitted to them for driving the piston; and more especially when that steam was boiled off directly from water without the introduction of additional heat to it after its evaporation. The knowledge of this, which was derived through important advances made in thermo-dynamic science, led to the introduction into ordinary use in steam navigation of steam-jacketed cylinders, and to the ordinary use also of superheated steam.

With increased efforts towards economy of space in the hold of the ship, which became the more essential when very long voyages were to be undertaken, and with the new requirement of greatly increased pressure in the steam, the old marine boilers, with their flues of riveted plates, were superseded by tubular boilers more compact in their dimensions and better adapted for resisting the high pressure of the steam. In connection with these various changes the old difficulty of the growth of stony incrustations in the boilers became aggravated rather than in any way diminished. As the only available remedy for this, there ensued the practical development and the very general introduction of the previously known but scarcely at all used principle of surface condensation instead of condensation by injection. A supply of distilled water from the condenser is thus maintained for feeding the boilers, and incrustations are avoided. The consumption of coal is often found now to be reduced to about 2 lbs. per indicated horse-power per hour, from having been 4 or 5 lbs. in good engines in times previous to about twenty years ago.

Before the times of ocean telegraph cables, very little had been done in deep-sea sounding; but when the laying of ocean cables came first to be contemplated, and when it came afterwards to be realized, the obtaining of numerous soundings became a matter of essential practical importance. In the ordinary practice of deep-sea sounding, as carried on, both before and since the times of ocean telegraph cables, until a year or two ago, a hempen rope or cord was used as the sounding line, and a very heavy sinker, usually weighing from two to four hundred-weight, was required to draw down the hempen line with sufficient speed, because the frictional resistance of the water to that large and rough line moving at any suitable speed was very great. The sinker could not be brought up again from great depths; and arrangements were provided, by means of a kind of trigger apparatus, so that when the bottom was reached the sinker was detached from the line and was left lying lost on the bottom; the line being drawn up without the sinker, but with only a tube, of no great weight, adapted for receiving and carrying away a specimen of the bottom. For the operation of drawing up the hempen line with this tube attached, steam power has been ordinarily used, and practically must be regarded as necessary.

(To be continued.)

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EDITORIAL.

ITEMS AND NOVELTIES.

On the Distribution of the Heat Developed by Collision. —The following account of a very curious and striking phenomenon, observed during the forging of the 250 kilogram ingot of platinum-iridium, made for the standard meter, was communicated to the French Academy, on June 8th, by the distinguished Engineer and Metallurgist, M. Tresca. We take the translation given below from *Nature*, No. 255:—

Many of our colleagues who have become aware of a fact in thermodynamics which it has been in our power recently to observe, think it possessed of so great an interest that I ought immediately to announce it to the Academy. It is as follows:—

During the forging, which has been very successful, of the ingot of platinum-iridium for the standard meter, I at first remarked that it sometimes produced, under the action of the hammer, luminous streaks, having an oblique direction upon the lateral faces of the piece, when this, while cooling, was yet at the temperature of a dull red. I showed some of these effects to M. Fizeau, but they were then incomplete, and I have only lately succeeded in obtaining a good observation of the phenomenon, and in defining its character with perfect certainty.

It is known that when a bar of metal is lengthened by means of a powerful hammer on an anvil of the same form as the head of the latter, each blow produces, above and below, a symmetrical contraction, the effect of which is to give to the bar the aspect of a series of projections separated by small level spaces.

At the time of the collision, these spaces, which are formed before and behind the impress of the hammer, upon the upper and the lower faces of the bar, are connected, at a certain moment, upon the lateral faces, by luminous lines passing from the one to the other, and presenting altogether the appearance of an X written in lines of fire. The phenomenon is only visible for a certain temperature of the bar which is being wrought, but then each blow invariably produces its effect, and, in consequence of the confused mingling of the imprints, we see the entanglement of these crossed lines which encroach upon each other. These brilliant bands appear at the same moment as the collision, but they do not disappear with it, and their continuance was sufficiently prolonged to enable us to count six luminous cross-bars visible at one time, although developed by six successive blows of the hammer.

I have been able, moreover, to get this persistence confirmed by several persons in the foundries of M. Farcot, who, with the greatest kindness, placed his services at the disposal of the Metric Commission for the execution of the work.

Although the lines of the cross-bars appeared to us all rectilinear, and although we could not compare them to anything better than two series of straight lines, parallel and intercrossed, we think it will be indispensable to determine their form more exactly by appropriate processes, and to discuss it with the greatest care.

It is well known that hammering develops heat in the bodies hammered; thermodynamics teaches us that these thermal effects ought to be regarded as the result of mechanical work or of *demi-force vive* exerted during the collision, but the precise place in which the calorific development is produced has not yet been noticed.

For ourselves, we do not hesitate to affirm that the zone which becomes luminous is that along which the matter mainly flows, at the moment when the change of form takes place, according to a law which we were enabled to discover in our previous researches in molecular displacements. If this first indication should be confirmed, there would be thus obtained a more exact knowledge of the mode of distortion determined by the forging, and the phenomenon which we describe would evidently form a new scientific connection between thermodynamics and the question with which we ourselves are personally occupied under the title of "Flowing of Solid Bodies."

The phenomenon ought to be the same for all metals, and we have already ventured to hazard some considerations of the particular causes of the brightness which it presented in the case of platinum, and which has not, so far as we know, been yet observed in any other forging.

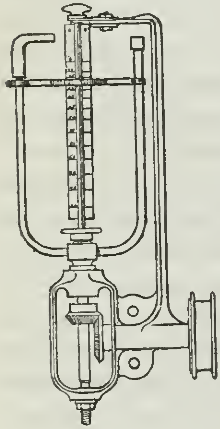
The exceptional hardness of the platinum-iridium, cooled to a dull red heat, requires, for an equal distortion, an amount of work at least equivalent to that of the forging of steel, and in consequence of the relative smallness of the calorific capacity of this alloy, this same work ought to be converted into calorific phenomena, more localized and more intense. Moreover, the material is more homogeneous than iron, and is notable for a kind of remarkable translucency which makes one believe that the eye can follow the shade of red to a certain depth. The effects, whatever they may be, are thus rendered more manifest, more especially as they are not accompanied by any exudation of foreign matter nor by any oxidation of the surface. All these circumstances are eminently favorable to the observation which chance permitted us to make, and which, once confirmed in the case of platinum, may certainly be renewed with other metals, although possibly in a more restricted manner than in the case of the alloy of MM. Deville and Debray.

We confine ourselves for the present to a summary indication of the principal fact, which appears to us to have a certain importance, and which consists in this appearance of luminous bands which arise from collision, and the position of which enables us to fix the precise place where is developed the heat which represents under another form the work done by motion; this fact is, perhaps, of a nature to open some new path for the researches, so carefully made, of the physicists of our epoch on all that touches on molecular mechanics and on the calorific actions which are connected with them.

The ingot of platinum has already been brought into the form of a bar with a square section of 4·50 m. in length; there will be a chance of continuing the same observations in the new operations of forging to which it will be submitted; the chance of renewing them may perhaps not again be offered.

Simultaneous Lighting of Street Lamps.—We see it announced in foreign journals that the city of Heidelberg has just introduced a recently invented system of instantaneously lighting the street lamps. By means of a small apparatus, very easily applied to each burner, the gas is made to light itself as soon as the pressure becomes sufficiently great. Towards midnight, when the pressure generally is diminished, certain parts of the flame are extinguished, while a portion remains lighted until morning, when the general distribution of gas ceases. It would appear that this apparatus is free from the great complication which has hitherto prevented similar devices from coming into general use.

Revolution Indicator.—Among the novelties in the Exhibition of the Franklin Institute, is a Revolution Indicator, invented and patented here and abroad by Mr. Ed. Brown of Phila. This instrument shows at a glance, by the height of a column of mercury the number of turns per minute made by a steam engine, without either counting or using a watch. It differs from the Engine Counter commonly used, which registers continuously the turns made per hour or day, but does not indicate the speed at any instant of time, simply by inspection, as does the Revolution Indicator. Its construction we will briefly describe by the aid of the annexed cut: The arm on the left is hollow, and is filled with mercury; it communicates with the central glass tube by means of a stuffing-box. The arm on the right is solid, and acts as a balance weight; it is connected with the mercury arm by a hollow strap. Upon revolving the instrument, the mercury falls in the central glass tube, and the speed per minute is indicated upon the scale-plate immediately behind it. The machine on exhibition has been running several weeks, attached to an engine driving the machinery, and appears to be remarkably accurate and sensitive, showing even a quarter turn in 60 revolutions. For the many engines which have to run at varying speeds for different operations, and also for engines controlled entirely by hand, the Revolution Indicator will be found particularly useful. When applied to marine engines, the accurate indication of this instrument will be somewhat influenced by the heel



of the ship, and possibly some of the mechanical devices in which clock-work is used may be preferred; though we are informed by Mr. Brown that its error at 20° is only 2 per cent.; and at 10° is less than one per cent.; and that its simplicity of construction, durability, and accuracy will make it more practically useful than instruments theoretically more perfect but also more complicated in construction.

W.

Statistics of Paper-making.—Some curious statistics relative to paper-making have been published by Rudel, of Vienna. It appears that there are 3,960 paper manufacturers in the world, employing 80,000 men and 180,000 women, besides the 100,000 employed in the rag trade; 1,809 millions of pounds of paper are produced annually; one half is used in printing, a sixth for writing, and the remainder for packing and for other purposes. The United States, with 3,000 machines, produces yearly 200,000 tons of paper, which for a population of 28,000,000, average 17 pounds per head. An Englishman consumes 11½ pounds; a German 8 pounds; a Frenchman 7 pounds; an Italian 3½ pounds; a Spaniard 1½ pounds; and a Russian only one pound annually, on an average.

Electro-deposition of Iron.—At the August Session of the Frankfort Society of the Physical Sciences, a memoir was read by M. Volger, upon the recent progress of electro-metallurgy and particularly upon the electro-deposition of iron. After giving a rapid review of the principal facts connected with the history of the galvano-plastic art, the memoir classes the directions of its development under three heads, as follows:—1st, where metallic forms are to be coated with other metals; as in electro-gilding, silvering, coppering, steeling, nickeling, etc. 2d, where the object is to imitate the plastic arts, and to take the place of metal casting. This special application is due to M. de Kress, who, at first at St. Petersburg, in 1845, and then successively at Frankfort, Offenback, Carlsruhe, Darmstadt, and finally at Mayence, has organized establishments in which the art has been carried to the highest perfection, as well for the smallest objects of nature as for the grandest works of art, among which may be mentioned the three colossal figures of the printer's monument at Frankfort, and the small tablets representing agricultural subjects, which are his especial invention. 3d, where the reproduction of works of art is the object; that is to say, the duplication of engraved plates, and the preparation of electrotypes. It is in this last class that the greatest progress has been made.

So far as the electro-deposition of iron is concerned, it is now nearly forty years since M. Peligot succeeded in reducing iron chloride by passing hydrogen over it. In this way he obtained metallic iron in octohedral crystals and succeeded in making some small malleable plates. In 1846, M. Boettger made the first attempts to decompose iron chloride by the voltaic current, and obtained excellent results. He soon perceived, however, that a mixture of ammonio-ferrous sulphate and of ammonio-ferrous chloride, was more advantageous for electro-deposition, and he prepared it very simply by dissolving together two parts by weight of ferrous sulphate and one of sal ammoniac. For the anode he used a plate of sheet iron, and a plate of tin-plate iron for the cathode. In this way, M. Boettger made with great perfection, a coin of iron. The specimens of iron thus made were extremely hard and steely, but were also, unfortunately, very brittle, and so fragile that they broke in pieces in taking them from the mould· Hence no applications of this process on any industrial scale were possible.

In 1859, M. Jacquin rendered the above process capable of useful application, by making known a method of steeling engraved plates, that is to say, of depositing an excessively thin layer of iron upon these plates, without at all impairing the fineness and the delicacy of the engraving, but communicating to the copper thus protected a hardness comparable to that presented by a plate of steel. For this process, the method of electro-deposition proposed by M. Boettger is the best thus far discovered and has been generally adopted

Very recently, M. Klein, of St. Petersburg, has remarkably perfected the electro-metallurgy of iron. Even in 1868, he had submitted to the Academy of Sciences of St. Petersburg some excellent results which he had obtained with a solution of ammonio-ferrous sulphate, a Meidinger battery, and a sheet iron plate used as the anode. M. Klein prepared in this way, by electro-precipitation, not only entire plates of this sheet-like iron, from the hardest to the softest, for the purpose of reproducing engraved copper plates, which united to the advantages of softness, for the purpose of engraving, of copper plates, that of hardness in the steely iron, for printing; but also plates showing its availability in the working of iron. In all cases however, the iron precipitated by M. Klein is very sharp and brittle, the cause of which he found to be hydrogen which had combined with it and which had lessened its specific gravity to 7·675, that is to say, a little above that of rolled iron. By annealing, however, this hydrogen may be expelled and the iron may thus be given a density of 7·811, surpassing that of forged iron; it is now perfectly malleable, eminently flexible and elastic, and like sheet steel, may be welded; in a word it possesses all the characteristics of an excellent forged iron.

M. Volger placed before the Society some of these steel plates taken from engraved copper plates, prepared by M. Klein, a block made of scrap welded together, forged, filed and polished, and also a shield of the size of a plate, representing in raised work, the Battle of the Amazons in rare perfection. M. Klein has prepared a similar plate weighing seven and a half kilograms.

The highest and most important use of electro-siderurgy is in its employment in stereotyping, especially in reproducing plates from which bank-notes are to be printed, postage stamps and the like-colored objects, since the iron will stand well without injury the mercurial colors so fatal to copper, to type-alloy and to other metals.

Bibliographical Notices.

THE CONSTRUCTION OF MILL DAMS. 8vo., pp. 336. *Springfield, Ohio*, 1874. *James Leffel & Co.*—As stated in the preface, a considerable portion of the matter of this book has appeared from time to time in *Leffel's Illustrated Milling and Mechanical News.* After being carefully revised and considerable new matter added, it is now republished in a handsome volume of more than three hundred pages, illustrated with numerous full page engravings. In this form it must prove, we think, of great value to builders of dams. The examples given cover nearly all the conditions under which mill dams are built, the materials which are used, and the variety of designs and expedients adopted to overcome natural difficulties. There is also much useful information concerning the building of embankments, and the measurement of streams and water supplies. The easy style and the absence of abstract formulæ will make the work of especial value to the non-professional worker, while the clear statistical statements of some of the largest works of this kind in America cannot fail to be useful to the professional engineer. K.

Franklin Institute.

Hall of the Institute, Oct. 21st, 1874.

The meeting was called to order at the usual hour, with the President, Mr. Coleman Sellers, in the Chair.

The minutes of the stated meeting held September 16th, were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at their stated meeting, held October 14th, the following donations to the Library had been reported, to wit:—

[See the Journal for October, 1874, pp. 234–235.]

The Actuary likewise reported the minutes of the several standing committees.

The President next announced a paper by Mr. Alexander E. Outerbridge, on "The Spectroscope in its application to Mint Assaying." The paper contained the results of an investigation undertaken by the author, to determine the possibility of establishing a practical method of quantitative spectrum analysis upon the basis of Lockyer's discovery that, under certain conditions, the lines of the metallic spectra do not entirely cross the field of vision, but break in the middle. The paper was amply illustrated with the aid of projections upon the screen. The conclusions reached were unfavorable to the practicability of the process. The paper was discussed by Messrs. Nystrom, Wahl, and the author.

The President next announced a paper by Mr. John E. Caldwell, of Pittsburgh, "On Hemphill's Balanced Slide Valve," being a description, illustrated by diagrams, of a recent invention of this character. The question as to the originality of certain novel features claimed by the inventor was discussed by Messrs. Le Van, Wiegand, and the author.

The Report of the Secretary next followed, which, amongst other matters of a technical nature, gave a description of the Automatic Gas Regulator of Messrs. Allen & French, which was exhibited at the meeting.

The President made the announcement that he had been called upon by Mr. Sterne, of Thompson, Sterne & Co., limited, Westminster, England, who had shown him certain samples of ground discs of hard steel (the President therewith exhibited the specimens), which had greatly interested him on account of their perfection. He had asked the loan of the discs, seven in all, $2\frac{7}{8}$ inches diameter, and ·027 inch thick, to show the members at this meeting. The seven plates placed one on the other, appear to be one solid disc of steel. To grind these plates, a magnetic chuck had been designed. This chuck, attached to a lathe spindle, is magnetized by a Gramme machine, and held the plates firmly while being operated on by the grinding machine. Mr. Sterne had stated also, that chucks of a larger size have been used to hold iron plates during the turning or planing operation.

The President next read a communication from Mr. William P. Tatham, in relation to the life-boat of the U. S. Government, now in the Institute Exhibition, and read the following resolution, which Mr. Tatham had requested him to make on his behalf:

Resolved, That a committee be appointed to examine and test the life-boat now in the Exhibition, and to report what modifications, if any, should be made to adapt it for our coasts, and also to examine the question of the best construction of life-boats for ships at sea.

The resolution was duly seconded and passed, and the President appointed the following members to serve upon the committee:—Messrs. G. N. Tatham, Charles S. Close, and John C. Trautwine.

Messrs. Burleigh, Close, Bullock, Orr and Le Van then occupied the floor, upon the question of admitting to the Exhibition, under certain regulations, the pupils of the public schools, and of certain charitable institutions, such as the Northern Home for Friendless Children, and the like. The whole subject was finally referred to the Committee on Exhibition.

Mr. Hector Orr next called the attention of the meeting to the recent death of one of the prominent members of the Institute, Mr. John W. Murphy, and in appropriate words moved an invitation to Mr. Le Van to present to the meeting an account of the life and services of the deceased. Mr. Le Van thereupon presented the following

BIOGRAPHICAL NOTICE OF JOHN W. MURPHY, C. E.

By W. Barnet Le Van.

It is with sentiments of more than ordinary regret I have to announce the death of one who has been a member of this Institute and has for many years past occupied a prominent position in connection with engineering science, and who, both by his writings and his works, has left an ineffaceable imprint upon the times in which he lived. I have reference to John W. Murphy, C. E., who on Sunday, September 27th instant, after a brief illness, closed an active and useful life, although having only attained the age of 47 years.

Mr. Murphy was born at New Scotland, in Albany County, New York, in the year 1828, his father being a farmer. During his youth he showed great proficiency for mathematics and surveying, and was placed with Mr. Wm. Henry Slingerland, a noted surveyor, and at the age of 15 years received a certificate from him that he was fully accomplished for the above profession, which bears date, Bethlehem, New York, November 15, 1843.

In April, 1847, at the age of 19, he entered Rensselaer Institute, at Troy, N. Y., from which he graduated in April, 1848, taking two degrees, B. N. S. and C. E. He was the most industrious student of his class. In addition to the studies necessary for graduation, he completed successfully the mathematics of the post graduate course. The extra labor cost him a severe fit of illness, which followed immediately upon his graduation.

In 1849 he was appointed Second Assistant of the Engineers in charge of the Western Division of the Erie Canal, under Squire Whipple. While connected with Squire Whipple, Mr. Murphy and he first introduced "Pin Connections" in Bridges, a most important step forward in Bridge Engineering. Zerah Colburn, in a paper read by him before the British Institute of Civil Engineers, some years ago, refers to and upholds the claim of Squire Whipple and Mr. Murphy to the introduction of this now almost universal connection in American bridge building.

About this time he designed a Suspension Bridge at Wibir Hill, across the Mohawk. This bridge had a vertical truss, to insure *stiffness*, the plan being original with him.

From 1851 to 1852 he was employed at Montgomery, Alabama, in erecting levees on the Alabama river.

In 1853–54 he built, under contract, a wooden bridge from the designs of F. C. Lowthorp, C. E., at Easton, Pa. It was obligatory by his contract that the work should be executed during the spring and summer months; he found that the rafts that came floating down the river made it impossible for him to erect this bridge in the ordinary manner, that is to say, by placing trestles or false works in the stream, upon which the superstructure would ordinarily be erected.

He devised the following novel plan: Wire ropes were suspended from pier to pier, and placing stanchions upon them, braced in the usual way, and made a temporary bridge, upon which he erected the main superstructure, by which means the rafts passed freely underneath, without danger to his workmen or the raftsmen, who were obliged to float upon the high currents of the Delaware.

In 1856 he began to build iron bridges, on the plan known as the Murphy-Whipple plan. The first of these was on a branch of the Lehigh Valley Railroad, and the second a double track bridge for the Beaver Meadow Railroad.

It was at this time he insisted upon determining the limit of elasticity of bridge iron as being of quite as much importance as the breaking weight, and urged the necessity of testing the different irons; he devised and constructed a testing machine. The idea was considered rather novel at that time by most engineers.

Between 1855 and 1857 he was in partnership with George W. Plympton, at Trenton, N. J., under the firm name of Plympton & Murphy. The financial panic of the latter year put an end to their bridge building. He then took up his residence in Philadelphia, and was connected with the erection of a large number of bridges, of which he was the designer.

In 1859, in company with Levi Line, George B. Algernon and Percival Roberts, under the firm name of A. & P. Roberts & Co., he being the Chief Engineer, and I. P. Morris & Co. the builders of the iron work, he erected for the U. S. Government seven bridges for Beal's Wagon Route, on the Plains, four of which were 100 feet, and three 50 feet spans, on the Whipple plan, with cast iron arches. Also one of 65 feet span, with draw, over Frankford Creek, Bridesburg; one of 50 feet span on the Foglesville Railroad, one of 165 feet span, on the Murphy-Whipple plan, over the Delaware, at Easton, for the Lehigh Valley Railroad; one of 160 feet span, for the Illinois Central Railroad, under Gen. McClellan; two of 125 feet span over the Jordan Creek, at Allentown, for the Lehigh Valley Railroad Co., and one of 50 feet span, for A. Campbell & Co., over the canal at Manayunk. This bridge, when finished, was remarkable for its lightness, being sent to its location in a furniture car, but they refused to receive it, as they did not believe it would answer the purpose intended. The bridge was, nevertheless, erected, and is standing at this present time in as good condition as when erected, and for the first six years carried a 4-inch line of shaft, which transmitted over 50-horse power to the opposite side of the canal; also a 4-inch water main, and the carriage of the products of their large mill, of 20,000 spindles.

During the years 1860 and '61 he occupied the position of Chief Engineer of the City of Montgomery, Ala., but upon the breaking out of the war, although offered great inducements to remain and cast his lot with the Confederacy, his love for the Union was so paramount in his mind that in escaping from the surveillance under which he was placed until he freely assured them of his choice, he was compelled to leave, forsaking behind him all of his instruments, papers, library, and other valuable interests.

In 1863 he was called upon by the U. S. Government to replace a bridge over a branch of the Gauley River, in West Virginia, destroyed by General Wise, General Rosencrans having command in that department. Mr. Murphy agreed to erect it in twenty-five days. He immediately proceeded to work, and on the twenty-third day it was ready for use. It was a suspension bridge, 520 feet in length, 10 feet roadway, consisting of three spans, supported by eight cables. There was some doubt in the mind of the commanding officer that it would answer the purpose for which it was erected, and so intimated to him. To test it properly and convince those in authority, he asked that a battalion be ordered to make a charge over it, which was done, to the satisfaction of the General in command. It was thus proven that their fears were groundless, and it afterwards passed and repassed the whole command as long as they occupied that portion of the country. A change of base put it into the possession of the Confederates, who burnt it down.

In June, 1864, he designed and erected the Union Hall, in connection with the building for the U. S. Sanitary Fair, in Logan Square, in forty days, he making the greater part of the drawings at his home at night. The truss arch of this building was purchased by the Pennsylvania Railroad Company, and is still used at the depot of departing trains for New York and Pittsburgh.

In the fall of 1869 he designed the Pipe Aqueduct crossing the valley of the Wissahickon at Valley Green, for the supply of Germantown, so as to avoid forming a trap, which was approved by Fred. Graff, Chief Engineer of the Water Department, December 7, 1869, and a contract entered into by him for its erection, which was finished during the summer of 1871.

This structure consists of two lines of flange pipes, 20 inches inside diameter, placed parallel to each other, at a distance of 14 feet from centre to centre, forming the compression chord of the aqueduct; each line of pipe is supported by two lines of wrought iron links, 10 square inches in section, attached to lugs cast upon the end pipes of each span; from these, vertical wrought iron columns 5 inches diameter, supported the pipes, entering into bosses upon the under side of the same; the whole is placed upon three piers, formed of four columns, each 8 inches diameter, stiffened by cross-ties and horizontal wrought iron beams. The aqueduct consists of four spans, each 165 feet 9 inches in the clear. The piers are 7 by 14 feet, resting on stone foundations.

In this structure he carried out the principle he introduced in 1854, in the erection of the bridge at Easton, over the Delaware, for supporting his superstructure, in place of trestle or false works, as is ordinarily used.

But his name will, perhaps, be best perpetuated in the new structure at South street, which is rapidly approaching completion. Under the authority of the commissioners appointed to carry on this public work, he received the contract for $770,000, and commenced his labors in 1870. The rapid construction of the work has been greatly interfered with by events that scarcely any contractor has been called upon to undergo. In attempting to found the piers on the western approach, he was arrested at the instance of the railroad companies, and bound over to court, for interfering with the passage of trains, and kept under bonds for a long period of time, until the assumed rights of the railroads were harmonized in the construction of the bridge by the commissioners.

On the eastern side the land was not condemned and jury appointed to assess damages until twelve months after signing of the contract, and some fifteen months' detention in the work was thereby occasioned, Mr. Murphy being arrested twice and placed under bonds for trespass, before all the conflicting interests were settled.

In the river delays occurred again by the passing tugs and tows, and severe loss was sustained by the wilful destruction of three of the pneumatic piles by a tug boat, which occasioned some three months' delay, the pier having been bolted to the bed rock of the river and filled with masonry, all of which had to be removed, and repairs made, and replaced.

The large amount of masonry to be laid across an alluvial deposit of earth, demanded extra caution and care in the construction thereof, and considerable time was required to secure permanent foundations for the magnificent line of arches which grace the western approach. The South Street Bridge commences at the intersection of Chippewa and South streets upon the eastern side, to the high ground of the Almshouse property beyond the Junction and West Chester Railroads on the west side of the river, connecting with Spruce street.

The entire length of the structure is 1934 feet 7 inches, consisting of two fixed spans 195 feet 8 inches each, and a draw 198 feet 2 inches in length, supported by a pier at each end of the draw and one in the centre to receive the pivot. Each end pier is formed by two columns of cast iron 8 feet in diameter, cast in sections ten feet in length, 1¾ inches thick, with inside flanges 2¾ inches wide, by 1¾ inches thick at top and bottom of each section. The flanges are pierced with holes 5 inches apart, from centre to centre, to receive 1¼ inch bolts. The bottom flange is omitted in the section forming the bottom of the column, when in position, for greater facility in penetrating the soil. This end is not beveled, as is generally done, but left square, so as to retain the full value of the thickness of the column for a bearing surface on the rock, each section weighing about 14,600 pounds, averaging seven sections to each column.

The pivot, or centre pier, is formed by a cluster of nine columns, a six feet column in the centre supporting the pivot of the draw, and a surrounding circle of eight columns 4 feet in diameter, carrying the track on which the draw revolves. This circle is 36 feet in diameter from out to out, while the pier columns are placed with their centres directly under the main chords of the bridge, making them 36 feet apart from centre to centre, and at right angles to the centre line of bridge, giving an opening of 77 feet on each side in the clear. The section of six feet columns average 10,800 pounds, and the four feet columns 6800 pounds each. These columns were cast from Government cannon, originally made from cold-blast charcoal pig, being an unexceptionable material for this purpose.

These columns were placed in position by the use of compressed air, by the plenum pneumatic process, as first adopted by Triger, in sinking a coal shaft on the Run Loye, in France, through a stratum of sand, &c., overlying the coal stratum, at the Bridge of Macon, and by John Hughes, at the Rochester Bridge, in England, and at Kehl, on the eastern border of France, in a railroad bridge across the Rhine, but more commonly known in this country as the pneumatic process.

In sinking these "pneumatic cylinders," Mr. Murphy introduced a more economical air-lock than was heretofore used, which enabled the workmen to pass from the normal atmosphere outside the column, to the denser atmosphere of the interior, and to prevent the escape of the compressed air while so doing. He also adopted, for the first time, brackets in sections, and extending clear around the whole inner circumference of the bottom of the column, and secured to its side by four 1¼ inch tap bolts; and to the rock by four bolts 18 inches long, with fox wedges at the lower end, and thread and nut on top, thereby adding much to the stability of the work. This was necessary on account of the small amount of holding ground for the cylinders, overlying the bed-rock.

The bed of the Schuylkill, at the site of the bridge, is a micaceous gneissic rock, undulating in surface, with overlying strata of sand, and tough, compact mud, intermingled with gravel and small boulders. Lying directly on the rock, considerable quantities of driftwood were found, its appearance evincing great age and a long occupation of its present position. The average depth of this bottom material is about thirty feet at the western pier columns, diminishing to only five feet at the eastern pier. At the draw the thickness is about eighteen feet.

The width of the approaches is 55 feet, consisting of carriage-way 35 feet wide, and two footways 10 feet wide on each side.

The eastern approach is 518 feet 10 inches in length, consisting of 363 feet 6 inches of broken range ashler retaining wall, of sandstone, and 114 feet 6 inches being three conoidal or flue arches of original design, composed of brick with stone rings and a granite abutment of 40 feet 10 inches, with pilasters and doric capitals.

The western approach is 826 feet 6 inches in length, consisting of 87 feet 4 inches of regular range ashler retaining wall of granite, and three trussed spans 244 feet 9 inches in length, supported by eight wrought iron columns over the Junction and West Chester Railroads, to an abutment of 62 feet 4 inches in length, and thence by nine brick arches of 43 feet 6 inches span, from centre to centre, with stone rings, 391 feet 3 inches long, with granite piers, to a granite abutment of 40 feet 10 inches, same character as eastern abutment.

Having referred to Mr. Murphy as an engineer, I will also speak of him as an author. He possessed the pen of a ready writer, and his contributions to the scientific literature of this country extend over a period of twenty years. He was a contributor to a great number of the scientific periodicals, and has read before this Institute a number of papers on different scientific subjects. His writings were distinguished by a very high order of style, and always forcible, practical, and convincing in argument, and, withal, agreeable and happy in his illustrations. At the time of his death he was engaged on a paper for this Institute, entitled "Bridge-Building Considered Normally," the first part of which will be found in the October JOURNAL, of 1873, page 242. He was an excellent speaker and a good conversationalist, and a most entertaining companion, being gifted with a retentive memory, he having during his life and in his intercourse with the world, come in contact with a great variety of persons. He was also a good musician, and wrote music with rapidity and harmony.

This man of great attainments has passed from among us, and his place knows him no more. His kindly genial face, and, above all, his warm hearted, generous, and impulsive nature, will long be remembered by those—and they are many—to whom for so many years they have been familiar. Mr. Murphy was twice married. By his first wife he had two children, a son and a daughter, whilst by his last he had no children. His children and second wife survive him. His death took place at his residence in Thirty-second street, in this city. The brief time at my disposal since his death, has been hardly sufficient to enable me to do justice to the memory of one who has played so prominent and varied a part in the history of engineering science as has Mr. Murphy. I feel assured that my shortcomings will not affect his merits, from which they cannot possibly detract, nor will my deficiencies impair the brightness of the memory of one whom, to know was to appreciate and respect, and whose character and attainments can cease to be admired only when they cease to be remembered.

Philadelphia, October 20, 1874.

The Secretary moved that the thanks of this meeting be tendered to the Directors of the German Society, for their courtesy in providing chairs for the meeting. Carried.

On motion, the meeting adjourned.

WILLIAM H. WAHL, *Secretary.*

Civil and Mechanical Engineering.

ON THE THEORIES OF STEAM-BOILER EXPLOSIONS.

By Dr. Ferdinand Fischer.*

Apart from the use of bad materials, from bad construction, and from bad workmanship, the alleged causes of steam-boiler explosions may be included under the following heads:—

1. Excessive pressure of steam.
2. Electrical action.
3. Explosive gases.
4. Spheroidal state.
5. Superheated water.
6. Sudden relief of pressure.
7. Shocks to the boiler.
8. Overheated plates.

1. *Excessive pressure of steam* is, only in the rarest cases, the direct cause of an explosion; that is to say, of so sudden a destruction of the boiler that it is torn into fragments, and these are projected to a distance. Such a violent result as this can have its immediate cause, according to Grashof,[1] only in the sudden conversion of a large amount of heat into work.

That boilers may, under certain conditions, sustain a very high steam-pressure notwithstanding the fact that they are so far damaged that upon inspection they may be perforated in various places by the blows of a small hammer, is well known.[2] The experiments of Andraud,[3] on the other hand, have shown that an iron boiler of 100 liters capacity, whose walls were two millimeters thick, could be burst

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[1] *Zeitschrift für die gesammten Naturwissenschaften*, 1872, 103.

[2] *Zeitschrift des Vereins deutscher Ingenieure*, 1869, xiii, 350.

[3] *Dingler's Polytechnisches Journal*, 1841, lxxix, 316; *Zeit. Ver. Ingen*, 1869, xiii, 152, 569.

by condensing air into it to a pressure of seventy-five atmospheres, but could not be exploded.

Moreover, the experiments of Stevens[4] and of the Commission appointed by the United States Government,[5] have proved that an excessive pressure of steam in a boiler in which there is a weak spot, causes simply a rent (or where the plates are brittle a piece may be blown out); while, when the plates are uniformly strong throughout, this pressure will, in all probability, cause a violent explosion.[6] The fracture of a boiler may, therefore, by suddenly relieving the pressure, be the occasion of its explosion; its rupture occasioning this explosion.

2. *Electrical action.* Andraud[7] maintains that by the evaporation of the water in the boiler, electricity is developed, which, under certain conditions, becomes capable of exploding. He therefore recommends the attachment of lightning rods to boilers. Jobard[8] is of the opinion that the electricity produced by the evaporation is sometimes collected on the numerous brass tubes serving as flues, as in a Leyden jar, and so produces a most destructive explosion. Tassin,[9] Wilke,[10] Hofmann,[11] Schiele[12] and others[13] also believe that electricity plays an important part in steam-boiler explosions. These suppositions, however, all of them evidently overlook the important fact that the electricity which may possibly become free can collect only upon the outer surface of the boiler, and that this surface is never insulated. Moreover, it is not easy to see how it is possible for electricity itself to explode.

Lardner[14] explained the explosion of a locomotive by attributing it to a stroke of lightning which so heated the boiler walls as to cause a sudden and violent evolution of steam, and so produced an explosion;

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[4] *Dingler's Polyt. J.*, 1872, cciv, 4.

[5] *Dingler's Polyt. J.*, 1873, ccxi, 412.

[6] *Dingler's Polyt. J.*, 1839, lxxiii, 401; 1841, lxxix, 234; 1842, lxxxiii, 10; 1867, clxxxvi, 84; *Zeit. Ver. Ingen.*, 1870, xiv, 215; Wiek's *Illustrirte Gewerbeztg.*, 1861, 56.

[7] *Dingler's Polyt J.*, 1841, lxxix, 316; 1855, cxxxvii, 24.

[8] *Dingler's Polyt. J.*, 1841, lxxix, 233.

[9] *Dingler's Polyt. J.*, 1841, lxxix, 234.

[10] *Zeit. Ver. Ingen.*, 1866, x, 571.

[11] *Zeit. Ver. Ingen.*, 1868, xii, 235; *Dingler's Polyt. J.*, 1867, clxxxvi, 84.

[12] *Zeit. Ver. Ingen.*, 1866, x, 569.

[13] *Zeit. Ver. Ingen.*, 1862, vi, 358; 1872, xvi, 786.

[14] *Dingler's Polyt. J.*, 1845, xcv, 249.

a statement, the possibility of which may be questioned. Not more probable is the hypothesis of Wilder,[15] that boiler-explosions are caused by the suddenly setting-free of caloric.

3. *Explosive gases.* Some years ago Perkins[16] asserted that explosions were frequently caused by the decomposition of the water of the boiler into its constituent gases; and Mackinnon[17] maintained that hydrogen was set free in the boiler by contact of the water with its highly heated walls; and that then, by opening the throttle-valve, air is allowed to enter, which mixing with the hydrogen, becomes ignited by the red hot plates and causes an explosion. Du Mesnil[18] is of the opinion that hydrogen is set free by the decomposition in the boiler of water and of oil-vapor, and that this coming in contact with the oxygen contained in the feed-water, forms an explosive mixture, which, being ignited by the plentifully generated electrical sparks, explodes and bursts the boiler. Schiele[19] believes that electrical sparks are produced in the boiler by the ebullition—just as lightning is produced in the clouds—and that these inflame the mixed gases and cause the explosion. Jobard[20] asserts that either water is decomposed by the ignited boiler-plates, or that, by the decomposition of the organic matter contained in the feed-water, a sort of fire-damp is generated. If now the tube of the feed-pump does not constantly dip below the surface of the water supplied to it, air is pumped into the boiler (?) and an explosive mixture of gases is thus formed; this, being ignited either by electric sparks or by the glowing organic matter within, causes the explosion of the boiler. Hipp[21] even maintained that the formation and ignition of explosive gases is the sole cause of boiler explosions; but his arguments on the point have been satisfactorily answered by Grashof.[22]

The investigations of a Commission appointed some time ago by the Franklin Institute of Pennsylvania,[23] have shown that water contained in a red hot boiler whose walls are clean but not polished, is not decomposed. And Schafhautl[24] has proved that one volume of oxyhydrogen gas will no longer explode, if mixed with 0·7 of a volume of steam. Parkes[25] indeed states that an inflammable gas is evolved during the blowing off of a highly heated boiler, which on opening the manhole, bursts into a flame; but, notwithstanding this, there can evidently be formed, during the hours of work, only the smallest possible traces of hydrogen. Even were large quantities of combustible gases evolved within the boiler, these would be so much diluted by the steam present, that even with a sufficient access of air and in presence also of ignited boiler plates—the hypothesis of electric sparks is completely absurd—an explosion of any magnitude is not to be thought of.

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[15] *Dingler's Polyt J.*, 1850, cxv, 87.

[16] *Dingler's Polyt. J.*, 1824, xv, 138.

[17] *Dingler's Polyt. J.*, 1832, xliv, 228.

[18] *Dingler's Polyt. J.*, 1842, lxxxiii, 7.

[19] *Zeit. Ver. Ingen.*, 1866, x, 569.

[20] *Dingler's Polyt. J.*. 1842, lxxxiv, 158; lxxxvi, 252; 1844, xciv, 344; 1846, cii, 407.

[21] *Zeit. Ver. Ingen.*, 1857, xi, 635, 753; 1869, xiii, 758; Hipp; die Gas bildung als Ursache der Dampfkesselexplosion (Baedecker, Coblentz).

[22] *Zeit. Ver. Ingen.*, 1867, xi, 762; 1869, xiii, 765.

[23] *Dingler's Polyt. J.*, 1836, lxi, 418; 1849, lxxi, 269.

Wolf and Taylor[26] assume as a cause, the explosion of gaseous products within the flues. If the stoker in charge, either at noon or at night, covers the glowing coal with a thick layer of slack or ashes, and closes the damper in the chimney, gases are formed, according to Jobard[27], which, when the fire-door is again opened and the fire is stirred, explode and destroy the boiler. Both Hänel[28] and Wabner[29] also emphasize the danger arising from such explosions in the fire-passages.

That inflammable gases may collect in the flues, is a well known fact; but that the explosion of these gases is sufficiently powerful to tear in sunder the boiler, is very improbable. Nevertheless, under certain conditions, especially in connection with the causes mentioned under 1, 5, and 7, these gases may be the indirect cause of a boiler explosion. At all events, prudence demands that after an intermission in the work, the damper should first be opened, and then the fire-door, so that in this way the explosible gases may be carried off.

4. *Spheroidal State.* Boutigny[30] regarded the so-called spheroidal state of the water in the boiler, as the chief cause of its explosion[31]. A white-hot metallic ball plunged into soap-water becomes immediately

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[24] *Dingler's Polyt. J.*, 1839, lxxi, 351.

[25] *Dingler's Polyt. J.*, 1842, lxxxiii. 21.

[26] *Dingler's Polyt. J.*, 1827, xxiv, 295; xxv; 279.

[27] *Dingler's Polyt. J.*, 1861, clix, 394.

[28] *Zeit. Ver. Ingen.*, 1867, xi, 164.

[29] *Dingler's Polyt. J.*, 1870, cxcvii, 377.

[30] *Dingler's Polyt. J.*, 1842, lxxxiii, 457; 1845, xcvi, 209; xcviii, 427; 1848, cvii, 241; 1851, cxix, 239, 464; 1850, cxvii, 394; 1851, cxxi, 48, 55, and 78.

[31] *Zeit. Ver. Ingen.*, 1869, xiii, 150 and 567.

surrounded with an envelope of vapor, and produces no hissing noise either at the time of immersion, or for some seconds afterward. But when this envelope of steam disappears from the ball by reason of its cooling, the water comes in contact with the hot ball, a sudden evolution of steam takes place, amounting almost to an explosion, and the vessel is generally shattered. A. W. Hofmann[32] has transformed this inverted Leidenfrost's experiment into a beautiful demonstration for the lecture-room. Barret[33] thinks that impure water in steam boilers takes the form of hollow (?) spheres; and that these exert, on bursting, a very strong tension. Normandy[34] indeed believes that he has actually observed such a spherical condition of the water in a steam-boiler. But it is very improbable, nevertheless, that such a phenomenon can occur frequently in a boiler, or can lead to its explosion.

5. *Superheated Water.* Dufour[35] has shown that drops of water ten millimeters in diameter, enclosed in oil, can be heated to 175° C., without the formation of steam. He has proved, still further, that under diminished pressure, considerable superheating may occur. Donny[36] succeeded in heating water, free from air, under the ordinary pressure, to 135° C. The corresponding observations of Schmidt[37], Krebs[38], Tyndall[39] and Gräger[40], are well known.

Dufour concludes from his experiments, that, during the period when the machinery is still, the steam-tension becomes lessened by the cooling of the steam-space, while the water continues to maintain its high temperature. By agitation, by opening the throttle, and the like, a sudden almost explosive boiling takes place, accompanied with a tumultuous formation of steam, which may prove destructive to the boiler. Heinemann[41], Kirchweger[42], Ruhlmann[43] and Reiche[44] question the possibility of such superheating of the water. Werner[45], Frohning[46], Ludewig[47], Blum[48], Scheffler[49], Jacobi and Fuhst[50], Langen and Stühlen[51], as well as Wittmann[52], on the other hand, maintain that it is entirely possible.

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[32] *Berichte der deutschen chemischen Gesellschaft*, vii, 535.

[33] *Ber. Berl. chem. Ges*, v, 814; *Mittheilungen des hannoverschen Gewerbevereins*, 1873, 102; *Zeit. Ver. Ingen.*, 1866, x, 155.

[34] *Dingler's Polyt. J.*, 1854, cxxxiii, 329.

[35] *Dingler's Polyt. J*, 1864, clxxiii, 266; *Poggendorff's Annalen*, cxxiv, 296.

[36] *Dingler's Polyt. J.*, 1847, ciii, 75; cv, 444.

[37] *Dingler's Polyt. J.*, 1866, clxxx, 403; *Zeit. Ver. Ingen.*, 1866, x, 209.

[38] *Dingler's Polyt. J.*, 1870, cxcvi, 101.

[39] *Dingler's Polyt. J.*, 1872, ccvi, 85.

[40] *Dingler's Polyt. J.*, 1873, ccvii, 338.

[41] *Zeit. Ver. Ingen.*, 1868, xii, 373.

[42] *Mittheilungen des hannoverschen Gewerbevereins*, 1870, 177; *Dingler's Polyt. J.*, 1871. ccii, 196

[43] *Hannoversches Wochenblatt für Handel und Gewerbe*, 1873, 132.

[44] *Dampfkessel*, 176.

Since, moreover, Burnat[53] and Mayer[54] have actually observed considerable superheating of the water in steam boilers, the possibility of such superheating, especially when the water is oily[55], or is free from air, must be conceded. But whether a good boiler can be destroyed by this agency alone, is entirely questionable. In conjunction with the causes mentioned under 1, 6, and 7, however, such an explosive kind of boiling may become the occasion of an explosion.

Donny[56] proposed to prevent the superheating of the water by blowing a fine stream of air into the boiler. Stiehl's[57] "explodicautor" acts by drawing up a small quantity of the water in the boiler and letting it fall again. Cohn[58] has made some experiments upon the use of electricity for this purpose.

Williams[59] asserts that liquid water always has the temperature of melting ice ; the heat apparent in hot water being due entirely to particles of steam distributed through it. He believes, therefore, that if there be too much water in a boiler, an explosion may take place on opening the throttle. How absurd these suppositions are, has already been shown by Meidinger[60].

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[45] *Zeit. Ver. Ingen.*, 1863, vii, 77 and 84.

[46] *Zeit. Ver. Ingen.*, 1865, ix, 600 ; 1867, xi, 346.

[47] *Zeit. Ver. Ingen.*, 1865, ix, 601.

[48] *Zeit. Ver. Ingen.*, 1866, x, 572 ; *Die Ursachen der Kesselexplosionen.* (Chemnitz ; Focke.)

[49] *Die Ursachen der Dampfkesselexplosionen.* (Berlin, 1867.)

[50] *Zeit. Ver. Ingen.*, 1868, xii, 403.

[51] *Zeit. Ver. Ingen.*, 1870, xiv, 341.

[52] *Zeit. Ver. Ingen.*, 1873, xvii, 694.

[53] *Zeit. Ver. Ingen.*, 1866, x, 345.

[54] *Zeit. Ver. Ingen.*, 1868, xii, 146 ; *Dingler's Polyt. J.*, 1867, clxxxiv, 298.

[55] On the injury caused by oily feed-water, see *Dingler's Polyt. J.*, 1857, cxlvi, 221 ; 1861, clxii, 164 ; 1864, clxxii, 109 ; 1865, clxxvii, 430 ; 1866, clxxx 254 ; 1868, clxxxvii, 431 ; 1869, cxciv, 82.

[56] *Dingler's Polyt. J.*, 1847, ciii, 75.

[57] *Dingler's Polyt. J.*, 1869, cxci, 181 ; *Zeit. Ver. Ingen.*, 1868, xii, 697.

[58] *Zeit. Ver. Ingen.*, 1870, xiv, 220, 619, 673.

[59] *Dingler's Polyt. J.*, 1861, clx, 161.

[60] *Dingler's Polyt. J.*, 1861, clxi, 1.

6. *Sudden relief of pressure.* Parkes[61] brings out the important fact, that of 23 boiler explosions investigated by him, 19 took place at the time of starting the machinery; others of these boilers exploded when the safety-valve was opened. The experiments upon boiler explosions which were undertaken under the direction of the Treasury Department of the United States, by a Commission of the Franklin Institute of the State of Pennsylvania[62], have shown that, when an opening is made into a boiler, there takes place at the point where the steam escapes, first a local foaming; and that then this foaming extends itself rapidly over the entire surface of the water in the boiler. This foaming is the more violent, the larger the opening into the boiler. The small experimental boiler used by the Commission, by opening the safety-valve—which was situated at about its center—was so completely filled with foam, that the water was ejected from it with great violence. To the same effect are the remarkable experiments of the Society of Engineers of Breslau[63]. A manufacturer of Bordeaux[64] explains the explosion of the steamboat "Citis" on the supposition that, when the throttle was opened, the hitherto quiet production of steam changed into a tumultuous boiling, the foaming muddy water obstructed the exit passage—the valve being constructed for the escape of steam, not for muddy water—and the boiler could not withstand the increased tension thus produced.

Reiche[65], on the other hand, is of opinion that by the sudden opening of the throttle, by the collapsing of a flue, and the like, a violent foaming takes place so that not only steam but a large quantity of water is discharged also; thus emptying the boiler and lessening the pressure upon it. The boiler explodes according to this theory, from a deficiency of water; but how, is unfortunately not stated.

If the steam-tension in a boiler be suddenly lessened, in consequence either of cooling by the entrance of water[66], of opening the throttle, of collapsing a flue, etc., a violent evolution of steam takes place, by which, under certain conditions, the water of the boiler is hurled with such force against its walls that they cannot resist the blow. This theory, first suggested by Colburn[67], is sustained by Bergius, Hofmann[68], Werner[69], and Kurz[70]. Grashof[71], especially, has proved that in consequence of this sudden evolution of steam following the superheating of the water, an actual explosion of the boiler may result. A gradually increasing pressure, as already mentioned, has only the effect of widening little by little, some crack in the most defective part of the boiler: a sudden, explosive increase of pressure, on the other hand, may produce an instantaneous explosion of the boiler at many places at once. The water being suddenly reduced to simple atmospheric pressure, evolves an enormous amount of steam, which, at the instant of its formation, has the pressure corresponding to the temperature of the water from which it was formed; the heat stored up in the water, is transformed into work, and thus causes the destruction. A fracture of the boiler somewhere, may therefore be the occasion of its explosion.

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[61] *Dingler's Polyt. J.*, 1842, lxxxiii, 20; *Zeit. Ver. Ingen.*, 1869, xiii, 449; 1873 xvii, 120, 122.

[62] *Dingler's Polyt. J.*, 1836, lxi, 324; lxii, 81; 1839, lxxi, 274; lxxiii, 401.

[63] *Dingler's Polyt. J.*, 1867, clxxxiv, 74; *Zeit. Ver. Ingen*, 1865, ix, 689.

[64] *Dingler's Polyt. J.*, 1841, lxxx, 313.

[65] *Dingler's Polyt. J.*, 1872, cciii, 84; *Zeit. Ver. Ingen*, 1871, xv, 673.

[66] *Dingler's Polyt. J.*, 1867, clxxxiv, 75.

Kayser[72] gives it as his opinion that the masses of steam which become free, almost explosively, as it were, by the sudden relief of pressure, may give so violent a blow on the boiler-walls, that these give way under the strain. While Grothe[73] and Kirchweger[74] call in question the possibility of such a sudden evolution of steam, and Cohn[75] declares that he has observed that no noticeable shock takes place on the sudden relief of pressure, Giesberg[76], Jacobi[77], Heinemann[78], Welkner[79] and others, accept essentially the theory of Kayser.

Ludewig[80] shows that the theory of Dufour in no way conflicts with that of Kayser, but that each supplements rather, the other. While according to Dufour, the opening of a safety-valve, etc., is only the mediate cause of the explosion, according to Kayser the explosion takes place on opening the valve, directly in consequence of the diminished pressure. To similar purpose are the statements of Hrabak[81] and Schröder[82].

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[67] *Dingler's Polyt. J.*, 1867, clxxxiv, 74; *Zeit. Ver. Ingen.*, 1869, xiii, 152.

[68] *Dingler's Polyt. J.*, 1867, clxxxvi, 84; *Zeit. Ver. Ingen.*, 1868, xii, 235.

[69] *Zeit. Ver. Ingen.*, 1869, xiii, 327.

[70] *Zeit. Ver. Ingen.*, 1870, xiv, 341.

[71] *Zeit. Ver. Ingen.*, 1867, xi, 762; *Zeitschrift für die gesammten Naturwissenschaften*, 1872, 103.

[72] *Zeit. Ver. Ingen.*, 1865, ix, 657; 1866, x, 129, 610; 1867, xi, 147; 1868, xii, 641, 668; 1869, xiii, 449; *Dingler's Polyt. J.*, 1868, clxxxvii, 518.

[73] *Mittheilungen des hannoverschen Gewerbevereins*, 1866, 161.

[74] *Mittheilungen des hannoverschen Gewerbevereins*, 1870, 177; *Dingler's Polyt. J.*, 1871, ccii, 196.

[75] *Zeit. Ver. Ingen.*, 1870, xiv, 609.

[76] *Zeit. Ver. Ingen.*, 1866, x, 141.

[77] *Zeit. Ver. Ingen.*, 1868, xii, 410.

[78] *Zeit. Ver. Ingen.*, 1868, xii, 365, 417.

[79] *Heusinger's Organ*, 1871, 67.

[80] *Zeit. Ver. Ingen.*, 1866, x, 573.

7. *Shocks to the Boiler.* Schafhautl,[83] in his experiments, filled some glass tubes, about five centimeters long, one-fourth with water, sealed them and plunged them into molten zinc whose fusing point is 412° C. They sustained well the enormous pressure of nearly 400 atmospheres, but exploded with great violence when touched with an iron bar vibrating longitudinally. He believes that no explosion is ever caused by excessive tension of steam alone, but that an explosion may take place from a vibratory motion of the boiler-walls ; indeed, that such explosions have already happened, caused, for example, from the blow of a hammer, or even from throwing a small stone against the boiler. Similar experiments have been made by Gensoul.[84]

That such a shock is competent, alone, to tear a boiler in pieces, is very doubtful ; but, in conjunction with the causes mentioned under 1 and 5, it may have its effect in causing the destruction of a steam-generator.

8. *Overheated Plates.* It is remarkable that, even at the present day, the heat necessary for the work of explosion is so often sought for, not in the water contained in the boiler, but in the overheated boiler-plates. Such an overheating may take place, but can only arise either from want of water, from the formation of incrustations, or from deposits of sediment.

Deficiency of Water. According to Carle and to statements from other sources,[85] if the water sinks below the fire-line, that portion of the fire-surface of the boiler which is no longer wet, becomes red-hot. If now the boiler be fed, or in the case of a ship's boiler, if the ship roll to one side, or if in any other way water comes in contact with the red-hot plates, so much steam is suddenly produced that an explosion is unavoidable.

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[81] *Dingler's Polyt. J.* 1867, clxxxiv, 295.

[82] *Dingler's Polyt. J.*, 1870, cxcv, 98 ; *Zeit. Ver. Ingen.*, 1869, xiii, 609.

[83] *Dingler's Polyt. J.*, 1842, lxxxiii, 11.

[84] *Poggendorff's Annalen*, xviii, 429.

[85] *Dingler's Polyt. J*, 1831, xxxix, 92; 1832, xliii, 242; 1838, lxvii, 81; lxix, 1; 1856, cxli, 14, 152.

Moreover, the experiments of the Commission of the Franklin Institute[86] have shown that by injecting water into a red-hot experimental boiler, a high pressure may be generated in a very short time; but Tassin,[87] on the other hand, reached no other result on pumping water into a red-hot steam-boiler, than to spoil the boiler.

More recent experiments[88] with a red-hot boiler prove that at the injection of the feed-water, the overheated iron strongly contracts, and this causes the boiler to leak around the rivet-holes. The experiments of Fletcher,[89] as well as those made by the Pennsylvania Railroad Company,[90] are to the same effect, and go to show that the explosion of an overheated boiler by the sudden injection of feed-water, is not even possible. Observations similar to these have been made by Oechelhäuser[91] and by Böcking.[92]

The assertion[93] that the steam, superheated by the red-hot boiler plates, is transformed by the water fed into the boiler, into saturated steam of so much higher tension that an explosion results, has already been disproved by the experiments made by the Franklin Institute.[94]

Perkins[95] maintains that, with a low stage of water in the boiler, the steam may become so strongly superheated, that not only the upper portion of the boiler, but even the part situated beneath the water, may become red-hot (?). On opening a valve anywhere, the water takes up this heat, forming instantaneously so much steam that the boiler cannot withstand the pressure. Marestier[96] and Loyer[97] are of the same opinion.

Not more happy is the hypothesis of Sawyer[98] that the level of the water in a steam-boiler changes in consequence of the unequal pressure upon its surface; and that in this way a portion of the boiler-surface is laid bare and overheated, and so gives rise to an explosion.

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86. *Dingler's Polyt. J.*, 1836, lxi, 347; 1839, lxxi, 268.
87. *Dingler's Polyt. J.*, 1841, lxxix, 234.
88. *Dingler's Polyt. J*, 1867, clxxxiv, 75; *Zeit. Ver. Ingen.*, 1864, viii, 189.
89. *Dingler's Polyt. J.*, 1867, clxxxiv, 218; *Zeit. Ver. Ingen.*, 1868, xii, 54.
90. *Dingler's Polyt. J.*, 1872, cciv, 354.
91. *Zeit. Ver. Ingen.*, 1868, xii, 667.
92. *Zeit. Ver. Ingen* , 1869, xiii, 544.
93. *Dingler's Polyt. J.*, 1856, cxli, 14.
94. *Dingler's Polyt. J.*, 1850, cxv, 85.
95. *Dingler's Polyt. J.*, 1827, xxiv, 484; xxv, 353; xxvi, 394; 1839, lxxiii, 82, 401.
96. *Dingler's Polyt. J.*, 1829, xxxi, 257.
97. *Dingler's Polyt. J.*, 1839, lxxi, 73.
98. *Dingler's Polyt. J.*, 1850, cxv, 86.

Incrustations and Deposits of Sediment. That boiler-plates which are covered with thick incrustations, may become red-hot, has long been known. Now if these deposits, resting on red-hot plates, be suddenly raised, an explosion may take place, due to the violent evolution of steam.[99] Cousté[100] has even asserted that when we are able to prevent the formation of incrustations in boilers, there will be no more boiler-explosions.

Williams[101] concludes from his experiments that crystalline solid incrustations are less dangerous than porous ones, formed by the solidifying of the sediment, since they conduct the heat far better. Peschka[102] also regards the deposits of sediment as more dangerous than the solid incrustations.

Although it is very doubtful if the steam formed by the rising up of a deposit can alone cause the explosion of a boiler, yet it is quite possible that the plate thus suddenly cooled may become fractured. Moreover, the indirect dangers arising from the fact that red-hot iron has far less strength than that which has not been overheated, and that the plates may burn out and be used up still more quickly than would be the case without a failure of water or the formation of an incrustation, is not to be overlooked.

According to the experiments of the Franklin Institute Commission,[103] an iron plate retains when heated red-hot only one-sixth of its original resistance; yet, theoretically, the tenacity of iron ought to reach its maximum at a temperature higher than the usual temperature of steam. So also, according to Wertheim,[104] many metals, and particularly iron, possess a maximum of elasticity at mean temperatures. Other authorities,[105] on the contrary, state that iron at 300° C., is sixteen per cent. stronger than when cold.

According to Kupfer,[106] the diminution of elasticity for each degree centigrade is expressed, in parts of the whole, as follows :—

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[99] *Dingler's Polyt. J.*, 1839, lxxi, 283; 1840, lxxvi, 152; 1842, lxxxiii, 20; lxxxvi, 257; 1850, cxv, 15; 1860, clvi, 460; 1872, cciv, 92.

[100] *Dingler's Polyt J.*, 1852, cxxv, 260.

[101] *Dingler's Polyt. J.*, 1842, lxxxv, 1; *Zeit. Ver. Ingen.*, 1867, xi, 210.

[102] *Zeit. Ver. Ingen.*, 1870, xiv, 238.

[103] *Dingler's Polyt. J.*, 1839, lxxi, 266.

[104] *Poggendorff's Annalen*, 2 Ergänz-Bd, 61.

[105] *Dingler's Polyt. J.*, 1850, cxv, 94; *Zeit. Ver. Ingen.*, 1868, xii, 383.

[106] *Memoire de l'Academie de St. Petersbourg*, 6, serie vi, 1856, 400.

For Iron,	0·00055
For Copper,	0·00082
For Brass,	0·00039

Especially noteworthy, however, are the recent investigations of Kohlrausch and Loomis.[107] If the modulus of elasticity at 0° C. be indicated by E^0, then at the temperature τ it is :—

For Iron,	$E=E^0(1-0·000447\tau-0·00000012\tau^2)$
For Copper,	$E=E^0(1-0·000520\tau-0·00000028\tau^2)$
For Brass,	$E=E^0(1-0·000428\tau-0·00000136\tau^2)$

If the definition of modulus of elasticity be referred, not to the unit of length, but to the transverse section, the factors of τ in the case of iron, change to 0·000483, in that of copper to 0·000572, and in that of brass to 0·000485. According to this, the elasticity diminishes by an increase of temperature from 0° to 100° C:—

For Iron,	from 4·6 to 5·0 per cent.
For Copper,	from 5·5 to 6·0 per cent.
For Brass,	from 5·6 to 6·2 per cent.

The second column of numbers here given refer to the second definition of the modulus of elasticity. Hence the statement that these metals possess a maximum of elasticity at mean temperatures is not correct.

Moreover, the later American experiments on steam-boiler explosions[108] have shown that the power of resistance of a boiler-plate against steam pressure is quite notably diminished by heating it.

Overheating of the boiler-plates, therefore, diminishes still more the still remaining tenacity of the metal. Indeed, according to the experiments of a committee appointed for the purpose,[109] the tenacity of overheated iron amounts to only two-thirds of that originally present. The rivets diminish its strength in like manner, about one-third; so that boiler-iron ought never to be subjected to any greater pressure than one-fifth part of its normal strength. Schafhautl[110] has observed that a boiler which at first worked well under a pressure of twenty atmospheres pressure, after it had been overheated by allowing the water in it to get low, exploded under a pressure of twelve atmospheres. The overheated iron, too, had become strongly contaminated with sulphur. Indeed, the danger that the iron will take up sulphur from a pyritiferous coal, increases materially at high temperatures.

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[107] *Poggendorff's Annalen*, cxli, 481; *Zeit. Ver. Ingen.*, 1872, xvi, 198.

[108] *Dingler's Polyt. J.*, 1874, ccxi, 412.

[109] *Dingler's Polyt. J.*, 1850, cxv, 90, 95.

[110] *Dingler's Polyt. J.*, 1839, lxxi, 362.

Ward[111] has made some observations on the temperature of two boilers. He found below the water-line temperatures varying from 131·6° to 135·5°, and in the steam space, from 201° to 260° (evidently in consequence of radiation from the boiler-walls). The water-surface oscillated up and down about fifteen centimeters, so that at some points within the boiler a sudden variation of temperature of 128° took place. That such differences of temperature as this, and consequently also, the strains produced by the various amounts of expansion of the different parts of the boiler, may be materially increased by overheating the plates, needs no formal statement.

Heated boilers, under otherwise similar conditions, explode far more easily than when the same pressure is applied to them cold. A boiler exploded not long ago, under a pressure of only three atmospheres, which had been previously tested by cold hydraulic pressure, up to nine atmospheres.[112] The cold-pressure test is therefore regarded in many quarters as completely worthless.[113]

In conclusion, if we take into consideration the great loss of fuel occasioned by boiler incrustations—according to Cousté,[114] 40 per cent.—as well as the important fact that muddy and impure water foams strongly, stops up the water-gauges and the manometer, and that the sediment itself is even carried over into the engine,[115] there is ground enough for the opinion that the formation of incrustations and boiler deposits is the worst enemy of steam industry.[116]

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[111] *Dingler's Polyt. J.*, 1866, clxxix, 240.

[112] *Dingler's Polyt. J.*, 1844, xciv, 339.

[113] *Dingler's Polyt. J.*, 1872, cciv, 10.

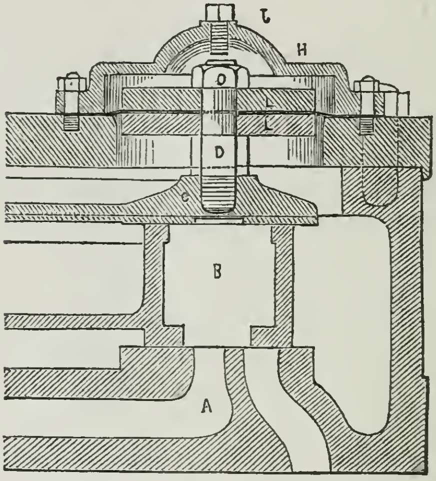
[114] *Dingler's Polyt. J*, 1852, cxxv, 260.

[115] *Dingler's Polyt. J.*, 1836, lxii, 434; *Zeit. Ver. Ingen.*, 1868, xii, 416.

[116] *Dingler's Polyt. J.*, 1874, ccxii, 208.

DESCRIPTION OF A NEW BALANCED SLIDE VALVE.*

By John A. Caldwell, of Pittsburgh.



(Fig. 1.)

In Fig. 1, A is the usual valve seat, and B the valve which slides between the seat and the relief plate C. The relief plate is kept from moving in the direction of the travel of the valve by means of arms standing out from its sides and held between jogs cast on the sides of the steam chest, leaving it free to expand from the middle towards each end of the steam chest. The faces between which the valve slides, are rendered flexible or yielding to each other in the following manner: the stem D made of wrought iron is tapped into the relief plate, and on this stem are slipped two circular plates L L of cast iron of sufficient thickness to remain straight under the pressure of the steam; sandwiched between these plates is a copper diaphragm 1-16th of an inch thick, the diameter of which reaches out to the bolts which hold down the bonnet H to the steam chest lid, the plates L L being bound to the stem by the nut O on top. The length of that part of the stem marked D is such that the under side of the copper stands 1-16th of an inch above the top of the steam chest lid. When the bonnet is put on, the edges of the copper are drawn down to the steam chest lid; this not only forms the necessary joint, but also seats the valve properly. The internal area of the bonnet H is made equal to the area of the extreme edges of the valve, minus the area required to secure the necessary downward pressure to keep the valve on the seat.

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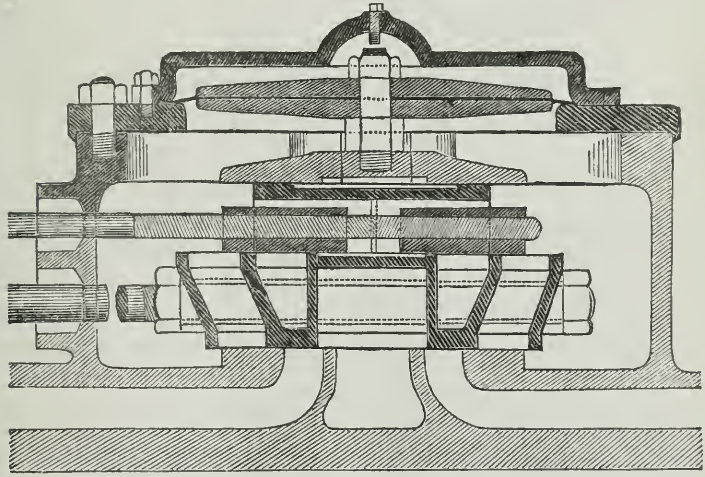
* A Paper read at the meeting of the Franklin Institute, held October 21, 1874.

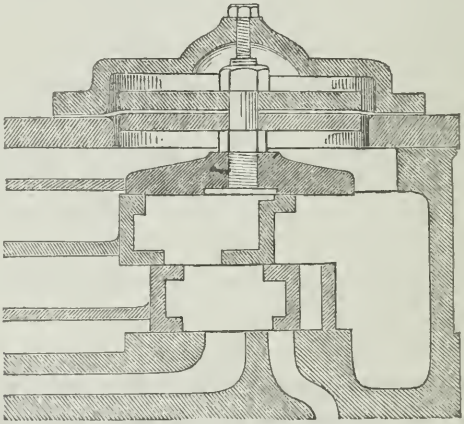
Fig. 1 shows the valve in its simplest form as adapted for an ordinary high pressure, double parted cylinder. On these engines a small hole is drilled in any part of the bonnet to admit the atmosphere, and ascertain when any leakage is going on. For condensing engines where the pressure at B and A falls below the atmosphere, a small pipe is led from the exhaust at A to the interior of the bonnet H. The same arrangement is used on locomotives, also, where the pressure rises considerably at B and A owing to the choking of the exhaust by the action of the link motion. If the valve is to be made to rest lighter on the seat, the bonnet H is removed, and its interior diameter enlarged. If the valve requires to be planed, the depth of the cut is made up by inserting a copper washer between the lower plate L and shoulder D. The coppers have worked four years without renewing. Cylinders above 30 inches diameter have two stems D, with 1 bonnet; cylinders from 45 upward, have four bonnets and four stems, one on each corner of steam chest. In case of water in the cylinder and the valve jerking off its seat, the copper yields 1-16th of an inch without injury. A bolt J keeps it from rising more than that. The bolt J is cut the right length, and is screwed down to the head to prevent its being tampered with.



(Fig. 2.)

Figs. 2 and 3 show its adaptation as a cut off valve. The former has plates on the back of the main valve which are moved to and from each other by means of a right and left hand screw operated by a hand wheel on the eccentric rod while the engine is in motion, thereby producing variable cut off. The latter has one valve on the back of the other and set permanent, and is operated by one eccentric, or made variable by two eccentrics, with link motion or otherwise. In this case the two valves are nearly balanced, and with the plates on back of the valve, the surface in contact will prove downward pressure. The cavity in the main valve over which the plates are shown in Fig. 2 is open at the ends and consequently that part of the plate passing over it is balanced.

The slide valve here described was patented by James Hemphill, of Pittsburgh, May 26, 1868.



(Fig. 3.)

[Entered according to act of Congress, in the year 1873, by John Richards, in the office of the Librarian of Congress at Washington.]

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

[Continued from Vol. lxviii, page 275.]

TURNING LATHES.

In machinery the ruling form is cylindrical sections; in structures other than machinery that does not involve motion, the ruling form is rectangular.

Motion in machinery is mainly rotary; and as rotary motion is accomplished by cylindrical parts such as shafts, bearings, pulleys and wheels, we find that the greater share of machine tools are directed to preparing cylindrical forms.

If the apprentice will note the amount of turned, bored and drilled surface in ordinary machinery, compared to the amount of planed surface in the same machinery, he will find the former not less than as two to one in the better class of machinery, and as three to one in the coarser class of work; from this he can see approximately the proportion of tools needed for operating on cylindrical surfaces and on plane surfaces, which, assuming that the cutting tools had the same capacity in the two cases, would be in the ratio of three to one.

In practice, the truth of the proposition is fully demonstrated by the excess in the number of lathes and boring tools over those for planing.

The Engine Lathe is for many reasons called the master tool in machine fitting. It is not only the leading tool so far as performing the greater share of the work, but the engine lathe as an organized machine combines perhaps a greater number of useful and important functions than any other machine that has ever been devised.

A lathe may be used to turn, bore, drill, mill, or cut screws, and with a strong screw feed, may be employed for planing of some kinds. But what is still more strange, notwithstanding these various functions, a lathe is a comparatively simple machine without complication or perishable parts, and requires no special change in adapting it from one purpose to another.

For milling, drilling and boring ordinary work within its range, a lathe is by no means a make-shift tool, but performs these various operations with nearly all the advantages of machines adapted to these different processes.

An ingenious workman who understands the adaptation of a modern engine lathe of American manufacture, can build almost any kind of light machinery without other tools, except for planing, and may even perform the planing when the surfaces are not too large; and what is still stranger he can in this way build machinery at a cost almost as small as though he had a full equipment of tools to use.

The lathe as a tool for producing heliacal forms would occupy a prominent place among machine tools even were it capable of no other work; the number of parts in machinery that have screw threads is astonishing when we consider them; clamping-bolts to hold parts together constitute alone a large share of the fitting in machines of all kinds, while screws are the most common means for increasing power and performing adjustments.

A Finisher's engine lathe consists essentially of a strong inflexible shear or frame, a running spindle with from eight to sixteen changes of motion, a sliding head, or tail stock with a dead centre, and a sliding carriage to hold and move the tools arranged to traverse on the shear by positive connection with the spindle.

For a half century past no great change has been made in engine lathes, at least no new principle of operation has been added, much improvement has been made in their adaptation and capacity, especially in adding to the convenience of operating upon various kinds of work.

During late years, improvements have been made in the facilities for changing wheels in screw cutting and feeding, in the use of frictional starting gear for the carriages, independent feed movement for turning, arrangements to adjust the tools, and for cross feeding and so on, adding no doubt greatly to the efficiency of lathes, but mainly supplanting the skill of lathemen.

A proof of this last proposition is found in the fact that a good turner will perform nearly as much work and do it as well on an old English lathe, with a plain screw feed, as can be performed on the more complicated lathes of modern construction ; but as economy of skill is sometimes an equal or greater object than economy of manual labor, an estimate as to tool capacity should be made accordingly.

The vital points in a lathe or such as many most readily affect its performance, are first—truth in the bearings of the running spindle which communicates a duplicate of its shape to the pieces that are turned,—second, coincidence between the line of the spindle and the movement of the carriage,—third, a cross feed of the tool at a perfect right angle to the spindle or to the carriage movement,—fourth, durability in bearing surfaces, especially in the spindle bearings and sliding track. To these may be added many other points such as the truth of the feeding screw, rigidity of the frame, and so on ; but these requirements are obvious.

To avoid imperfection in the bearings of the running spindle of lathes, or any lateral movement that might exist in the running bearing there have been many attempts to construct lathes with a dead centre at both ends for the more accurate kinds of work, an arrangement that would produce a true cylindrical rotation of the piece, but at the same time involve mechanical complications and difficulties that outweigh the object sought; besides it has been proved in practice that good fitting, and good material in the bearings and spindles, insures all the accuracy that ordinary work demands.

The apprentice will notice that in some lathes the carriages move on what is termed V tracks that project above the top of the lathe frame, and that in other lathes the carriages slide on top of the frame with a flat bearing. As these two plans of mounting lathe carriages have led to considerable discussion on the part of different makers and as its consideration may suggest a plan of analyzing other questions of a similar nature, I will notice some of the conditions that must be considered in the two cases, calling them by the names of flat shears and track shears.

These two plans of track shears and flat shears must be considered first in reference to the effect produced upon the carriage action, such as endurance of wear, rigidity of the tools, convenience of operating and the cost of construction.

The cutting point in both turning and boring on a lathe is at the side of the piece or the hole, and any movement of the carriage horizontally across the lathe shear effects the motion of the tool directly and to the extent of such movement, so that parallel turning and boring depend mainly upon avoiding any cross movement or side play of a carriage on the lathe shear. The movement of the carriage parallel to the line of the spindle and the work is best maintained by wearing surfaces at a right angle to this horizontal movement or by surfaces normal to the shear tops, or to state it in less words the parallel movement of lathe carriages in a vertical plane is dependent upon vertical bearing surfaces. In this respect there is not much difference between the flat shear and track shear, except in the angle of the bearing surfaces which will be noticed further on.

A true movement of the carriage in a vertical plane is especially important in boring with a bar, but in the case of using fixed tools as in turning, and in chuck boring, deviation of the carriage in a vertical plane is of but trifling importance compared to deviation in a horizontal plane.

To prevent deviation of lathe carriages horizontally, or across the shear the two planes of the flat shear and the track shear are not much different as a rule in the extent of wearing surface, but with a flat shear the stress upon the carriage falls upon but one side of the shear, while with V guides it falls on both sides.

The strain in turning, or the thrust of the cut as it may be termed, falls on a carriage usually at an angle of about thirty degrees from the spindle downward toward the front of the lathe; this strain is very great, and is of course best opposed by bearing surfaces at a right angle to the line of the force, and so arranged as to employ the whole strength of the shear to resist it. Neither of these conditions is filled by the flat shear, as this cutting strain falls mainly on the gib at the back of the lathe, and at an acute angle with the bearing surfaces; this strain also falls only on one side of the shear, and unless there are a great number of cross girts, has but one-half its strength to withstand the thrust of the tool.

With a track shear that has double ways, both sides of the shear equally resist the tool thrust or cutting strain, and the bearing surfaces stand at, or nearly at, a right angle to the line of the force.

A carriage moving on V tracks always moves steadily and can have no play in any direction until lifted from its bearing, and the lifting is easily opposed by adjustable gibs; while a carriage on a flat shear is apt to have play on the shear in a horizontal direction because of the freedom that it must have to secure easy movement. In the case of the tracks it may also be mentioned that the weight of the carriage acts as a constant force to hold it steady, while with the flat shear the weight of the carriage is in a sense opposed to the gibs, and has no useful effect in steadying or guiding it.

The rigidity and steadiness of the tool is notoriously in favor of the triangular tracks, so much so that nearly all American manufacturers construct their lathes in this manner, although it adds no inconsiderable cost in fitting.

It may also be mentioned that the track shears usually have a triangular way for the moving head as well as for the carriage, which leads to the advantage of firmly binding the shear together in fastening the moving head, which in effect becomes a strong girt across the frame at the end of the work.

The reader will, in following this matter thus far, see how many conditions may have to be considered in reasoning about so apparently simple a matter as the form of ways for lathe carriages, and may even go on to many more points that have not been mentioned; it shows how abstruse a matter it is to reason about mechanical problems even when the premises are all at hand and seemingly clear.

The lathes in common use for machine fitting are screw cutting engine lathes, lathes for turning only, double geared, single geared, and back geared lathes, lathes for boring, hand lathes, and pulley turning lathes; also compound lathes with double heads and two tool carriages. These are common modifications which the apprentice can soon familiarize himself with by remembering this classification, or assuming one of his own.

These various lathes, although of a widely varied construction and adapted to uses more or less dissimilar, are still the engine lathe, either with some of its functions omitted to simplify and adapt it to some special work, or with some of the operative parts compounded to attain more capacity.

In respect to lathe manipulation, which is perhaps the most difficult to learn of all shop operations, I will give the following hints that may prove of service to the learner:

At the beginning, study the form of tools; this is one of the great points in lathe work; the greatest distinction between a thorough and indifferent latheman is that the first knows the proper form and temper of tools and the latter does not. The adjustment and presenting of tools is soon learned by experience, but the proper form of tools is not soon learned. One of the first things to study is cutting angles, both as to clearance below the edge of the tool, and the angle of the edge itself with reference to turning, and also for boring, which is different from turning. The angle of lathe tools is clearly suggested by diagrams, and there is no better first lesson in drawing than to construct diagrams for cutting angles on plane and cylindrical surfaces.

A set of lathe tools should consist of all that are required for every variety of work that comes to the lathe, so that no time is lost in waiting to prepare tools after they are needed. An ordinary twenty inch engine lathe operating on ordinary work will require from twenty-five to thirty-five tools, which will serve for every purpose if they are kept in order and kept in place. A workman may get along with ten tools or even less, but not to his own satisfaction, nor in a speedy way. Each tool should be properly tempered and ground, ready for use "when put away;" if a tool is broken, it should at once be repaired, no matter when it is likely to be used. A workman who has pride in his tools, will always be supplied with as many as he needs, because it takes no computation to tell that fifty pounds of extra cast steel tools as an investment, is but a small matter compared to a little gain in manipulation by having the tools at hand.

To an experienced mechanic a single glance at the tools on a lathe is a sufficient clue to the skill of the workman who operates the lathe; if the tools are ground ready to use, of the proper shape, and placed in order so as to be reached without delay, the user is at once to be set down as having two of the main qualifications of a first class workman, which are order, and a knowledge of tools; while on the contrary, a lathe board piled full of old waste, clamp bolts, and broken tools, shows a want of system and order, without which no amount of hand skill will make a workman.

It is also necessary to learn as soon as possible the technicalities pertaining to lathe work, and still more important to learn the conventional modes of performing the various operations. Although lathe work includes a large range of operations that are continually varied, yet there are certain plans of performing each that has by long custom become conventional; to gain an acquaintance with these the apprentice should watch the practice of the best workmen and follow their plans as near as he can, not risking any innovation or change until it has been most carefully considered. Any attempt to introduce new plans or modes of chucking work, setting and grinding tools, or other of the ordinary operations in turning may not only lead to awkward mistakes, but will at once put a stop to useful information that must be gained from others.

The technical terms used in lathe work are soon learned, generally sooner than they are needed, and often misapplied, which is worse than to be ignorant of them.

In cutting screws never refer to that mistaken convenience called a gear list, that is usually stamped on some part of engine lathes. The screw to be cut is to the lead screw on the lathe as the wheel on the screw is to the wheel on the spindle, and every workman should be familiar with so simple a matter as computing wheels for screw cutting, when there is but one train of wheels. Wheels for screw cutting are computed not only nearly as soon as read from an index, but the advantage of being familiar with wheel changes is very important in other cases, and frequently such combinations have to be made when there is no index at hand.

The following matters may be computed and studied with advantage in operating a lathe: the rate of cutting movement on iron, steel, and brass, the relative speed of the belt cones, whether the changes are by a true ascending scale from the slowest, the rate of feed at different changes estimated like the threads of a screw at so many cuts per inch, the proportions of cone or step pulleys to insure a uniform belt tension, (referring to the lathe and countershaft in use as an example) the theory of the following rest as used for turning flexible pieces, the difference between three and four bearing points in centre and following rests, the best means of testing the truth of the lathe. All these matters and many more are subjects not only of interest but of use in learning lathe manipulation, and their study will lead to a logical method of dealing with other questions that will arise continually in the fitting shop.

Learn to use hand tools by employing them on every possible occasion. A great many of the modern improvements in engine lathes are only to evade hand tool work, and in scarcely any case effect any saving except in skill. A latheman who is skillful with hand tools will on many kinds of light work perform more and do it better on a hand lathe than on an engine lathe, while there is always more or less that can be performed to advantage with hand tools even on the most elaborate engine lathes.

A Lancashire latheman, in a test that was made at Manchester, England, a few years since, in facing the hubs of wrought iron railway car wheels, exceeded the performance of the best slide lathes with his hand tools, both as to smoothness of the work and in the time required to perform it. It is no uncommon thing for one of these old hand tool lathemen to lock his slide rest and resort to hand tools on many kinds of work when he is in a hurry.

PLANING OR RECIPROCATING MACHINES.

The term planing should properly be applied only to machines that produce planes or flat surfaces, but the technical use of the term makes it include all cutting that is done in right lines, or by what may be called straight line movement of the tools.

As no motion can be continuous except rotary motion, and as rotary movement is almost exclusively confined to shaping cylindrical or circular pieces, the proper distinction between machine tools that operate in straight lines and those that operate with circular movement will be to call them rotary and reciprocating.

The apprentice will notice that all machines except milling machines that act in straight lines and produce plane surfaces have a reciprocating movement. This class includes planing, slotting and shaping machines, which, with lathes, makes up the greater share of finishing tools.

It is strange, considering the simplicity of construction and the very important office filled by machines for cutting on plane surfaces, that they were not sooner developed and applied in metal work; many men yet working at the trade can remember when all flat surfaces were chipped and filed, and long after engine lathes had reached a state of efficiency, planing machines were not known. This is no doubt to be accounted for in the fact that graduated and reciprocal motion, except that produced by cranks or eccentrics, was unknown or regarded as impracticable for such purposes until late years, and when finally applied it was thought impracticable to have such movements operate automatically. This may seem quite absurd to even the apprentice of the present time, yet the matter, as a mechanical problem, is by no means as simple as it may at first thought appear.

A planing machine platen for instance, moves at a uniform rate of speed each way, and by its own motion shifts or reverses the driving power at each extreme of the stroke; presuming that there were no examples to be examined, the apprentice will find many easier problems than to tell how a planer platen can shift its own belts. If the platen or table disengages the power that is moving it, the platen stops; if the momentum carries it enough farther to engage or connect other mechanism to drive the platen in the opposite direction, the moment such mechanism comes into gear the platen must stop and no movement can take place to engage clutches or shift belts. This is a curious problem that will be referred to again farther on.

Reciprocating tools are divided into those wherein the cutting movement is given to the tools, as in shaping and slotting machines, and machines wherein the cutting movement is given to the material to be planed, as in the common planing machine, and very strangely we find in general practice that tools for both the heaviest and the lightest class of work, such as shaping and cutting planers, operate upon the first principles, while work of a medium class is mainly performed on the second kind.

This problem of whether to move the material or to move the tools for the cutting motion, in planing, is an old one, and both opinion and practice yet vary to some extent, but machinists seem now to have settled down upon tolerably constant rules.

Judging upon theoretical grounds, and leaving out the mechanical conditions of operation, it would at once be concluded that the proper plan is to move the lightest body; that is, if the tools and their attachments are heavier than the material, then the material should be moved for the cutting action, and vice versa; but in practice there are other conditions to be considered that are more important than the question of relative weight in the reciprocating parts, and it must be remembered that in solving any problem pertaining to machinery the conditions of operation are to be considered first and have precedence over questions of strain, arrangement, or the general principles of construction. A standard planing machine, such as is used for most kinds of work, is arranged with a running platen or carriage upon which the material is fastened and traversed beneath the cutting tools. The uniformity of arrangement and design in machines of this kind throughout the world wherever they are used must lead to the conclusion that there are substantial reasons for this arrangement instead of having a cutting movement of the tools.

A planing machine with a running platen occupies nearly twice as much floor space, and requires a frame at least one third longer than if the platen was fixed and the tools performed the cutting movement. The weight, also, that has to be traversed, including the carriage, will in nearly all cases exceed what it would be with a tool movement; so that there must exist some very strong reasons in favor of the moving platen, which I will now attempt to explain, or at least to point out some of the more prominent that have no doubt led to the common arrangement of planing machines.

First it must be remembered that strains caused by the cutting action, in planing or other machines, fall within and are resisted by the framing, even when the tools are supported by one frame and the material by another. Such frames have to be connected by means of foundations, which are to be regarded as a constituent part of the framing in such cases. Direct action and reaction must be equal; if a force is exerted in any direction there must be an equal force acting in the opposite direction, so that every machine must absorb its own strains.

Keeping this in view and referring to an ordinary planing machine which the reader is presumed to be familiar with, I will assume the focal point of the cutting strain in a planing machine to be at the point of cutting and to radiate from this point as from a centre, and start from this cutting point and follow back through the mechanism to the frame proper; first starting with the tool and its supports, and secondly, from the material to be planed to the framing again, to examine what may be called the attachments.

Beginning at the tool there is first a clamped point between the tool and the swing block; second, a movable pivoted joint between the block and shoe piece; third, a clamped joint between the shoe piece and the front saddle; fourth, a moving joint where the front saddle is gibed to the swing plate or quadrant plate; fifth, a clamp joint between the quadrant plate and the main saddle; sixth, a moving joint between the main saddle and the cross head; seventh, a clamp joint between the cross head and standards; and eighth, bolted joints between the standards and the main frame; making in all eight distinct joints between the tool and the frame proper, three of which are moving joints and four clamped joints depending on friction alone, and one bolted joint.

Starting again from the cutting point, and going the other way from the tool to the frame, there is first a clamped and stayed joint between the material and platen, next a running joint between the platen and frame, and this is all; one joint that is firm beyond any chance of movement, and a moving joint that is not held by adjustable gibs, but by gravity, a force that acts equally at all times and is the most reliable known in mechanics.

Reviewing these mechanical conditions, the apprentice may at once see a sufficient reason for the platen movement of planing machines, and that it would be objectionable if not practically impossible to add the traversing or cutting action to the tool, that is already supported through the medium of eight joints, and to traverse for cutting would require a moving gib joint in place of the bolted one named last in the list.

This is not, however, the only reason that has led to the running platen for planing machines, although the most important one.

If the cutting movement was performed by the tool supports, it would necessarily follow that the larger the piece to be planed, and the greater the distance from the platen to the cutting point, the farther the tool must be from its supports; a reversal of the conditions required, because the heavier the work the greater the cutting strain will be, and the tool supports less able to withstand the strain.

It might be argued that the same conditions apply to the standards of a common planing machine, but the case is different; the upright framing is easily made strong enough by increasing its depth; but the strain upon a running joint is as the length of the bearing surfaces are to the distance at which a force is applied, when the force acts parallel to the bearing faces. With a moving platen the larger and heavier the piece to be planed the more firmly the platen is held down, and as the cross section of the pieces is presumed to increase with their depth, the result is that a planing machine that is properly constructed will act nearly as well on deep as on shallow pieces.

The lifting action on the platen at the front end is of course increased as the height at which the cutting is done above its top, upon the principle just stated; but this has not been found a difficulty of any importance in practice and has not even required extra length or weight in the platen, beyond what is demanded to receive the work and to resist flexion in fastening heavy work.

The reversing movement of the platen already alluded to is one of the most complex problems that exists in machine tools.

The platens as a rule run back at twice the forward or cutting movement, and as this is uniform throughout each motion and requires to be stopped at the extremes by meeting some elastic or yielding resistance, that, to use a steam phrase, "cushions" or absorbs the momentum, and starts the platen back for the return stroke.

This object is attained in planing machines by the friction of the belts, which not only cushions the platen like a spring, but in being shifted oppose a gradually increasing resistance until the momentum of the platen is overcome and its motion reversed. By multiplying the movement of the platen with levers or other mechanism, and by reason of the movement that is attained by momentum after the driving power ceases to act, it is found practicable to have a platen "shift its own belts," a result that would never have been reached by theoretical deductions, and was no doubt discovered by experiment, like the automatic movement of engine valves.

It is not intended to claim that this platen-reversing motion can not, like any other mechanical movement, be resolved by mathematical principles, but that the mechanical conditions are so obscure and the invention made at a time that warrants the supposition of accidental discovery. In fact the accomplished fact is barely a mechanical possibility as planing machines are now constructed. In the driving gearing of planing machines the conditions that most favor the reversing movement are high speed and narrow driving belts.

The time in which a belt may be shifted is as the speed and width of the belt; a belt to be shifted must be deflected or bent edgewise, and from this cause wind spirally in order to pass from one pulley to another. To bend or deflect a belt edgewise there will be required a force inversely as the width of the belt, and that when the belt is deflected by the shifters the time of passing from one pulley to another is as the number of revolutions made by the pulleys.

Planing machines of the most improved construction are driven by two belts instead of one, and many mechanical expedients have been adopted to move the belts differentially, so that both should not be on the driving pulley at the same time, but move one belt before the other in alternate order; an object that is easily attained by simply arranging the two belts with the distance between them equal to one and one-half or one and three-fourths times the width of the driving pulley; the effect is the same as that accomplished by differential shifting gear, with the advantage of admitting of adjustment as to the action of the two belts.

Another principle in planing machines that deserves notice is the manner of driving the platen, which is usually by means of spur wheels and a rack on its underside. The rack movement is smooth enough, and effective enough so far as a mechanical connection between the wheels and platen, but there is a serious difficulty to be met with in the torsion and elasticity of cross-shafts and a train of reducing gearing. In all other machines for metal cutting there is a studied object in having the supports for both the tools and the material as rigid as possible, but in the common type of planing machines, such as have rack and pinion movement, there is a controversion of this principle inasmuch as a train of wheels and several cross shafts constitute a very effective spring between the driving power and the point of cutting; a matter that is at once proved by planing across the teeth of a rack or the threads of a screw on a machine that is arranged with spur wheels and the ordinary reducing gearing. It is true the inertia of the platen is interposed and in a degree overcomes this elasticity, but in no degree that amounts to a remedy.

The planing machines invented by Mr. William Sellers and manufactured in America and in England, are free from this elastic action of the platen, which is moved by a screw pinion set on a shaft with its axis diagonal to the line of the platen movement, so that the teeth or threads of the pinion act partly by a sliding contact and partly by a progressive forward movement like the teeth of wheels. The rack on the platen is arranged with its teeth at a proper angle to balance the friction arising from the rubbing action of the pinion, which angle has been demonstrated as correct at 5°, the standard co-efficient of friction.

As the pinion-shaft is strongly supported at each side of the pinion and the thrust of the cutting force falling mainly in the line of the pinion shaft, there is but little if any elasticity in the gearing and the motion is positive and smooth.

This gearing has been described here mainly for the purpose of calling attention to what constitutes a new and singular mechanical movement, one that will furnish a most interesting study and one that deserves a more extended application in producing slow reciprocating movements. The drawings of the English patent office will furnish data and proportions for planing machine gearing of this kind.

(To be continued.)

Economy of Fuel in Furnaces.—M. Foucault, in a report to the Industrial Society of Rheims, combats the idea that the smokelessness of a fire can effect a notable saving in the amount of fuel burnt. He alleges also, on the other hand, that a considerable loss of economy is produced by smoke-consuming apparatus. He brings, in support of his opinion the long series of observations made by the Industrial Society of Mulhouse, which have proved that, with the ordinary boiler furnaces, it is only necessary to consume from 125 to 150 cubic feet of air for each pound of coal, while furnaces, for the most part, pass twice that quantity. If the draught be reduced in quantity much smoke is evolved, but the products of combustion, circulating more slowly, part with their heat more readily to the boiler flues. It is further proved that the best means of reducing the loss of heat by the chimney is by the use of feed heaters in the flue, so as finally to reduce to 200° the products of combustion which are often discharged as hot as 400°. Feed-water heaters well set, will produce an economy of from 11 to 20 per cent., with a reduced draught. The conclusion is that furnaces with large area and suitable feed-heaters are the most economical in all respects. But in order to obtain the best results much care is needed in stoking. A little at a time and often, should the coal be spread over the front of the fire, and the bright coal pushed back to the bridge. At the same time the least possible quantity of cold air should be admitted.

Chemistry, Physics, Technology, etc.

THE REAL REASONS WHY CASTINGS IN IRON ARE ACCURATE COPIES OF THE MOULD.

By Robert Mallet, C.E., F.R.S.*

The fact that cast iron does take very accurately the form of the mould in which it is cast has been for a length of time attributed to the supposed fact that the metal expands in volume while passing from the liquid to the solid state—a supposition which for more than a century has passed current, though without any sufficient proof. In a paper read before the Royal Society on the 11th of June last, an abstract of which, taken from the "Proceedings" of that society, has appeared in *The Engineer* for the 3d July last, I have disproved by two independent experimental methods the supposed fact that cast iron does expand in consolidation from fusion. The paper itself will probably be published in full by the Royal Society in the latter part of this year. Meanwhile it may be stated that the methods pursued consisted in, first, the determination of the specific gravity of liquid cast iron, by weighing equal volumes of the liquid metal and of distilled water, the specific gravity of the same cast iron at 60° Fahr. being also determined; secondly by determining the dimensions of a spherical shell of cast iron heated to bright redness, and then filled with liquid cast iron before being heated, when filled, and during the cooling back to the temperature of the atmosphere, when its dimensions were found the same as at the beginning; also by determining the specific gravities of the circumferential and central portions of the ball of cast iron when cold which had filled the shell. The central portions were found much less dense than the circumferential parts, as is well known to be the case in all castings in iron, of whatever size and form; but if the expansion in volume had taken place in the ball cooling by radiation, the central portions must have been found much more dense than the circumferential parts. The agreement of these two independent trains of experiment removes all doubt as to the completeness of the proof that cast iron does *not* expand in volume in passing from the state of liquid fusion to that of solidity by cooling; and it is therefore certain that the degree of exactness with

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which cast iron takes the form of the mould into which it is cast is to be otherwise accounted for. It is not necessary I should here advert to the objects in relation to certain lunar volcanic theories with which the above experiments were undertaken, nor to the conditions under which cast iron in the solid state may or may not float on cast iron in fusion; the latter facts, erroneously interpreted, having been, in fact, the foundation upon which the supposed notion of the expansion of cast iron during consolidation has been based. For these and the details of the experiments I must refer to the paper itself. In the meantime some useful deductions of a practical character may be drawn from the facts ascertained. Were it the fact that cast iron in solidifying *did* expand in volume, a little consideration will show that such expansion would result, not in the casting being an accurate copy of the mould—whether of green or dry sand, or loam—but must be a distorted copy, the expansion in volume of the metal filling the mould being, in effect, the same as if it were exposed to the hydrostatic pressure of a liquid pumped into it, the yielding to which would be greatest where the walls were least resistant, or where the force to which they are exposed is greatest—namely, where the surfaces exposed to pressure were the largest. Thus, for example, a flat plate moulded from a pattern of equal thickness throughout would when cast, be no longer of equal thickness throughout, but have one or both of its broad surfaces forced outwards so as to make the plate thickest towards the central parts, whilst the edges and corners of the plate which consolidate first would remain nearly unaltered, and the metal be found not even completely forced into contact with those parts of the mould; in fact, no form of casting except that of a sphere could under the supposed conditions of expansion in volume remain an undistorted ectype of the pattern, nor could any rigidity in the mould prevent this, the expansive force being by hypothesis irresistible, like that of water freezing into ice.

Cast iron does, however, as is well known, take the form of the mould, as formed of sand or loam by the usual methods of the founders, with great fidelity. We must except, however, the case of chills or massive moulds of cast iron, the liquid metal cast into which is so instantly chilled by contact as not to form a very accurate transcript of the mould. But though cast iron does take a very sharp and accurate transcript of the mould when cast, it does not do so to a greater extent than do several metals to which the supposed property of expanding or consolidation has never been attributed. Thus zinc affords castings of exquisite sharpness from sand moulds, as all those must have remarked who have seen the superb ornamental castings in that metal for architectural and other purposes which form the staple trade of the great German and Belgian zinc foundries. Lead also, when carefully preserved while in fusion free from oxidation and cast in slightly greased moulds so as to reduce any oxide formed therein, affords castings of exquisite sharpness, as may be observed in those of the ancient lead work of the roofs of churches and other buildings of from 200 to 300 years ago in France and Belgium. Gold, silver, copper, and most of their alloys, on the contrary, afford generally more defective castings and wanting in sharpness. The circumstances upon which these opposite results arise are extremely complicated, and to fully elucidate them would require more space than can be here afforded; they involve conditions mechanical, chemical, and molecular, affecting both the metal cast and the nature of the mould in which it is cast, as well as the relations of these to each other. Amongst these the following are, perhaps, the most important: First, the density of the metal itself. Whatever be the nature of the metal, it fills the mould when full under a certain hydrostatic pressure due to the height of the liquid column and to the density of the metal, and whatever the metal may be, this is the mechanical force by which it is compelled to follow and fill while liquid the sinuosities of the mould. Let us suppose the liquid head constant, say 2½ feet or 30 inches, we readily see how enormous a difference there yet is in the mould-filling force due to density alone in the five metals, aluminum (which gives extremely defective castings), zinc, cast iron, lead, and gold, their densities being:—

	Specific gravity.	Lbs. per sq. inch under 30-in. head.
Aluminum,	2·560	2·820
Cast iron,	7·110	7·856
Zinc,	7·146	7·896
Lead,	11·360	12·552
Gold,	19·340	21·371

Thus, in the last of these metals the hydrostatic pressure tending to fill the mould completely is about seven and a-half times greater than in the case of aluminum, and yet both these metals produce inferior castings, while the three intermediate metals afford sharp and good ones. Secondly, the specific capillarity when in fusion, and viscosity while passing from the liquid to the solid state. Different metals are liquid in very different degrees while in perfect fusion, and therefore require very different degrees of pressure to force them into angular cavities. Upon this point physicists have as yet given us but little exact information. The greatest diameter of spherical drops capable of being assumed by any metal when taken in connection with its density is, however, a rough measure of the resistance which each presents to being forced into angular cavities of a mould of such material that it is not wetted by the liquid metal; thus fluid solder will readily penetrate between the edges of two clean tin plates, but will not enter at all if the plates be tarnished or blackened by a candle flame. Drops of mercury cohere at larger diameters than those of liquid lead. So also different metals differ in the range of viscosity through which they pass between their state of most perfect liquidity and that of solidity. Lead and some of its alloys, such as plumbers' solder, pass through a very long range of viscosity; brass and copper do so likewise, though in less degree; cast iron, and in general all the metals that crystallize most readily and best, pass through a very brief stage of viscosity. Where the melting point of the metal is a low one, one of the effects of this prolonged viscous stage, during which the metal contracts by loss of heat, is that its withdrawal from the sides of the mould is not compensated by a sufficient continuance of hydrostatic pressure, owing to imperfect liquidity. Cast iron is remarkably free from this objection; its melting point being very high and its range of viscosity small and confined to a small range of temperature, the metal is maintained, though constantly contracting by loss of temperature, in close contact with the mould by hydrostatic pressure up to within a brief period of its setting. Thirdly, upon the tendency of the metal to oxidate or combine with other elements presented to it in casting, and producing compounds less fusible than the metal itself, greatly depends the perfection or imperfection of the castings produced from it. Fluid zinc oxidates but very slowly up to a temperature somewhat above its melting point, but it oxidates rapidly at and above a bright red heat; hence zinc gives perfect castings; but when it is alloyed with copper the melting point of the brass is raised to such a point that the zinc oxidates very rapidly, and produces that "tailing" and general scurfiness of surface which is the plague of the brass founder, and the oxide of zinc is not reducible back to metal at the temperature at which brass is cast by any chemical agent capable of being introduced into the substance of the mould. In cast iron, on the other hand, its tendency to oxidate by contact with the atmosphere when in fusion is opposed by the presence of silicon and carbon in the metal itself, and any oxide superficially formed is reduced back to metal with great facility by the hydrogen and carbonic oxide evolved from the moisture and charcoal, or coaldust, or other carbonaceous matter entering into the constituents of the mould. Gold is inoxidizable, but possesses a vigorous affinity for sulphur, and it is probable that the film which may be observed upon the surface of molten gold in casting, and which produces "tailiness" in the ingot or bar, consists of some sulphur compound taken up from the gases from the fuel employed for fusing it. Copper also casts badly, as when in fusion it is constantly either taking up carbon or oxygen as the heat of the furnace is either a reducing or an oxidating one, and the great cleanness of castings produced from phosphorized copper arises from the presence of the small amount of that element precluding it from taking up carbon, on the one hand, and shielding it from oxidation on the other. Fourthly, a high melting point and a high specific heat are favorable to the production of perfect castings, as prolonging the time during which *cæteris paribus* the metal filling the mould is subjected to its own hydrostatic pressure, thus more completely forcing it into sinuosities and expelling air bubbles or other gaseous matters. If the fusing point be very low, as in the case of lead or tin, the viscous point is so rapidly reached by the loss to the mould of the small amount of heat present in the metal that there is but little chance of air bubbles or particles of unreduced oxide being previously forced out. Fifth, the absolute amount of contraction of any metal between the temperature at which it is poured and that of the atmosphere, forms also an element in the perfect correspondence of the casting to the form of the mould in which it was cast. On comparing this rough sketch of some of the principal conditions upon which the degree of perfection of castings in various metals depends, it will be obvious that amongst all the metals commonly used for castings in the arts, cast iron occupies an extremely favorable position: its density is sufficient to press it when liquid effectively into the mould, its capillarity is not very great, its range of viscosity is small, and it possesses the paramount advantage that whatever oxide may be formed in the casting processes is precluded from becoming diffused throughout the mass by the silicon and carbon present, and that any oxide formed on the surfaces in contact with the mould is instantly again reduced by the hydrogen and carbonic oxide evolved from the mould itself. In these conditions, indeed, cast iron may be said to stand unrivalled amongst metals in the perfection of the castings made from it, and they are quite sufficient to account for that perfection without calling in the now disproved supposition that it expands like ice at the moment of consolidation. The experimental determination of the specific gravity of liquid cast iron adverted to at the beginning of this paper affords us the means—and for the first time—of determining the total dilatation in volume as well as the linear dilatation of cast iron of the quality experimented upon, viz., the fine-grained, bright gray tough cast iron employed by mechanical engineers. As the specific gravities of this iron when cold and when melted were 7·170 and 6·650, so that the unit in volume when cold being taken as 1000, was increased to 1078·2 at the temperature somewhat above the melting point at which the iron was poured; the total dilatation in volume being thus 0·0782, and this divided by three—*i. e.*, neglecting all but the first term of the series—gives for the total linear dilatation 0·02606, which, taking the whole range of temperature between 60° and 2400°, and if we assume the dilatation uniform throughout the range, gives a coefficient of dilatation of 0·00001086 for 1° Fahr. This, however, is not quite correct, as the rate of dilatation increases rapidly within a few degrees of the melting point. The dilatation found as above is also in excess of that due to the precise range between 60° and the melting point of cast iron, the higher temperature in my experiment being somewhat above the melting point, exceeding it by probably about 200° Fahr. My direct object being simply to prove that melted cast iron is not denser—as has been stated—than the same cast iron in the solid state, and not that of ascertaining the exact dilatation due to the precise range between 60° Fahr. and the melting point; we are enabled, however, incidentally to deduce the latter with approximate accuracy. I must reserve, however, for a future communication some further remarks upon this part of the subject, as also upon the interesting phenomena of the movements observable in large masses of liquid iron, as in the largest crane ladles, which have been erroneously appealed to as affording proof that liquid cast iron is denser as its temperature is higher.

MECHANICAL SCIENCE.

An Address delivered before the Mechanical Section of the British Association at its meeting in Belfast, Sept., 1874.

By Professor James Thomson, LL.D.

[Continued from Vol. lxviii, page 294.]

A great improvement has within the last two or three years been devised and practically developed by Sir William Thomson. Instead of using a hempen sounding line, or a cord of any kind, he uses a single steel wire of the kind manufactured as piano-forte wire. He has devised a new machine for letting down into the sea the wire with its sinker, and for bring both the wire and the sinker up again when the bottom has been reached. With his apparatus, in its earliest arrangement and before it had arrived at its present advanced condition of improvement, he sounded, in June 1872, in the Bay of Biscay, in a depth of 2,700 fathoms, or a little more than three miles, and brought up again his sinker of 30 lbs. weight, after it had touched the bottom; and brought up also an abundant specimen of ooze from the bottom, in a suitably arranged tube attached at the lower end of the sinker.

An important feature in his machine consists in a friction-brake arrangement, by which an exactly adjusted resistance can be applied to the drum or pulley which holds the wire coiled round its circumference, and which, on being allowed to revolve, lets the wire run off it down into the sea. The resistance is adjusted so as to be always less than enough to bear up the weight of the lead or iron sinker, together with the weight of the suspending wire, and more than enough to bear up the weight of the wire alone. Thus it results that the arrival of the sinker at the bottom is indicated very exactly on board the ship by the sudden cessation of the revolving motion of the drum from which the wire was unrolling.

Another novel feature of great importance consists in the introduction of an additional hauling-up drum or pulley arranged to act as an auxiliary to the main drum during the hauling-up process. The auxiliary drum has the wire passed once or twice round its circumference at the time of hauling up, and is turned by men so as to give to the wire extending from it into the sea most of the pull requisite for drawing it up out of the sea, and it passes the wire forward to the main drum, there to be rolled in coils, relieved from the severe pull of the wire and sinker hanging in the water. Thus the main drum is saved from being crushed or crumpled by the excessive inward pressure which would result from two or three thousand coils of very tight wire, if that drum unaided were required to do the whole work of hauling up the wire and sinker.

The wire, though exposed to the sea-water, is preserved against rust by being kept constantly, when out of use, either immersed in or moistened with caustic soda. The fact that steel and iron may be preserved from rust by alkali is well known to chemists, and is considered to result from the effect of the alkali in neutralizing the carbonic acid contained in the water, as the carbonic acid appears to be the chief cause of the rusting of steel and iron.

This new method of sounding, depending on the use of piano-forte wire, was first publicly explained by Sir William Thomson in the Mechanical Section of the British Association at the Brighton meeting two years ago; and in the interval which has since elapsed, it has come rapidly into important practical use.

I have to-day already brought under your notice a system of elaborately contrived and extensively practiced methods of signalling and otherwise arranging for the safety of trains in motion on railways. These methods, in the aggregate, as we have them at present, may be looked on as the result of a gradual development, which, through design and intelligent selection, has been taking place during the last twenty or thirty years, or more. In contrast with this I have now te mention a reform towards abatement of dangers at sea, which at present is only in an incipient stage of its practical application, but which I am sure must soon grow into one of the most important reforms of the future. I refer to the provision of means whereby every important lighthouse shall, as soon as it is descried, not only make known to the navigator that a light is visible, but also that it shall give him the much more important information of what light it is; that, in fact, it shall distinguish itself to him from all other lights either stationed on land, or carried by ships out at sea. The rendering of lighthouses each readily distinguishable from every other light, by rapid timed occultations, was urged on public attention by Charles Babbage about twenty or twenty-three years ago, in connection with a like proposal of his for telegraphic signalling by occulting lights. His admirable idea, however, so far as it related to the distinguishing of lighthouses, has unhappily been left almost entirely neglected until quite recently. Although I say it was almost entirely neglected, yet very important steps in the direction of the object proposed were taken many years ago by Messrs. Stevenson, engineers to the Commissioners of Northern Lights, and the flashing and intermittent lights introduced by them, and now used, although too sparingly, in various parts of the world, constituted a very great improvement in respect to distinctiveness. The first practical introduction of an intermittent extinction of a gaslight, which is a method now likely to become fruitful in important applications with further developments, was made many years ago by Mr. Wilson at Troon; and an admirable application of this plan by the Messrs. Stevenson to carry out the principle of rapid signalling is to be seen in the Ardrossan Harbor light, which is alternately visible for two seconds, and then for two seconds is so nearly extinguished as to be invisible. The whole period —four seconds—is, I suppose, the shortest of any lighthouse in the world. This light fulfils the condition of being known to be the light which it is, within five or ten seconds of its being first perceived; and thus, in respect to distinctiveness, I trust that I may without mistake say it is the best light in the world. Mr. John Wigham has succeeded in constructing large burners for the combustion of gas in lighthouses in general, including those of the first order, and embracing both fixed lights and revolving lights. He has also, in both these cases, applied with the most striking success, the principle of occultation. Dr. Tyndall, in his reports to the Board of Trade, has dwelt frequently and emphatically on the ease with which gas lends itself to the individualization of lights. By its application, he affirms that by simple arrangements it would be possible to make every lighthouse declare its own name. Within about the last two or three years the subject has been taken up energetically by Sir William Thomson. He has become strongly impressed with the enormous importance of the object in question. He has perseveringly labored in making trials in various ways, both by the method of partially extinguishing gas flames and by the method of revolving screens; and I have pleasure in stating that, as a result of his efforts, a self-signalling apparatus is now constructed for the Belfast Harbor Commissioners, who are preparing to bring it into immediate use at the screw-pile lighthouse at the entrance of the harbor of Belfast. I shall not now enter on any description of this arrangement, as I understand that the apparatus, which has already been temporarily erected for trial in the lighthouse, and has shown good results, is to be exhibited and explained to this Section by Mr. Bottomley, who, as a member of the Board of Harbor Commissioners, has taken an active part in the promotion of the undertaking.

I wish next to make mention of the very remarkable works at present in progress in the harbor of Dublin, under the designs and under the charge of Mr. Bindon Stoney. In order to form quay walls with their foundations necessarily deep under water, he constructs on land gigantic blocks of artificial stone, or, as we may say, of concrete masonry, each of which is about 350 tons in weight, and which are accurately formed to a required shape. After the solidification of the concrete, he carries them away and deposits them on an accurately levelled bottom of sea, so that they fit closely together, and form so much of the quay wall in height as to reach above the low tide level; and so as to allow of the completion of the wall above by building in the usual manner by tidal work, and to allow of the whole structure being carried out without the use of cofferdams. These operations are on a scale of magnitude far surpassing anything done before in the construction and moving of artificial stone blocks. They are carried out with machinery and other appliances for the removal and the placing of the blocks, and for other requirements of the undertaking, which are remarkable for boldness of conception and ingenuity of contrivance. The new methods of construction devised and applied in these works by Mr. Stoney are recognized as being admirably suited for the local circumstances of the site of the works in the harbor of Dublin, and their various arrangements form a very important extension of the methods of construction available to engineers for river and harbor works.

While progress has been made with gigantic strides in many directions, in engineering and in mechanics generally; while railways, steamboats, and electric telegraphs have extended their wonders to the most distant parts of the world; and while trade, with these aids, is bringing to our shores the produce even of the most distant places, to add to our comforts and our luxuries; yet, when we come to look to our homes, to the places where most of our population have to spend nearly the whole of their lives, I think we must find, with regret, that, in matters pertaining to the salubrity and general amenities of our towns and houses, as places for residence, due progress in improvement has not been made. Our house drainage arrangements are habitually disgracefully bad; and this I proclaim emphatically, alike in reference to the houses of the rich and the poor. We have got, since the early part of the present century, the benefit of the light of gas in our apartments; but we allow the pernicious products of combustion to gather in large quantities in the air we have to breathe; and in winter evenings we live with our heads in heated and vitiated air, while our feet are ventilated with a current of fresh, cold air, gliding along the floor towards the fire-place to be drawn uselessly up the chimney. A very few people have commenced to provide chimneys or flues to carry away the fumes of their more important gaslights, in like manner as we have chimneys for our ordinary fires. In mentioning this, however, as a suggestion of the course in which improvement ought to advance, I feel bound to offer a few words of caution against the introduction of flue pipes for the gas flames rashly, in such ways as to bring danger of their setting fire to the house. People have a strong tendency to require that such things as these should be concealed from view. In this case, however, special care should be taken against rashly placing them among the woodwork between the ceiling of the apartment and the floor of the room above or otherwise placing them in unsafe proximity to combustible materials. In many cases it would be better to place the flue exposed to view underneath the ceiling, and by introducing some accompanying ornamentation, to let the flue be regarded as a beneficent object not unpleasing to the eye.

The atmosphere of our large towns, where people live by hundreds of thousands all the year round, is not yet guarded against needless pollution by smoke, jealously, as it ought to be. Many of the wealthier inhabitants take refuge in living in the country, or in the suburbs of the town, as far away as they can from the most densely built and most smoky districts; but the great masses of the people, including many of all ranks, must live near their work, and for them at least greater exertions are due than have yet been made towards maintaining and improving the salubrity and the amenities of our towns. As to the abatement or prevention of smoke from the furnaces of steam-engines, the main requisites have long been very well known; but sufficient energy and determination have not yet been manifested towards securing their due application in practice. In too many cases futile plans have been tried, and on being soon abandoned have left a strong impression against the trying of more experiments; and this may account in part for the introduction of real improvements having been so slow. Smoke occurs when fresh coal is thrown suddenly, in too large quantity at once, upon a hot fire. By extreme care a fireman may throw coal into his furnace so gradually as to make very little smoke; but mechanical arrangements for introducing constantly and uniformly the new supply of fresh coal have been devised, and several of these have been such as to reduce the smoke emitted to almost nothing. I have seen in the neighborhood of Glasgow, at a large manufacturing establishment at Thornliebank, one method which is applied to about thirty ordinary 40 horse-power boilers, in which upwards of 100 tons of coal are daily burned, and from the chimneys of which not more smoke is emitted than from many a kitchen fire. This method is under the patent of Messrs. Vicars, of Liverpool, and it seems to work very well. It has been about two years in work there. It was introduced at a time when coal was exceedingly high in price, as much to effect economy in fuel as to prevent smoke; and although the first cost was somewhere about £130 per boiler, the proprietor considers himself to be already more than recouped for his outlay, as a saving of fully 12 per cent. in the fuel consumed was effected. At the same works I have also seen in operation the method of Messrs. Haworth and Horsfall, of Todmorden, which has, I am told, in certain circumstances, some advantages over the other. In this, as in the other, the coal is fed in uniformly by mechanical arrangements. The mechanism is different in the two cases, but the result in the motion communicated to the coal is very much alike in both. The bed of coal, which is gradually supplied in front, is caused to travel along the bars towards the inner end of the furnace, and the combustion proceeds in a very uniform manner in conditions highly favorable to economy of fuel, and almost without the emission of any visible smoke.

These two methods I have mentioned because they both appear to work very successfully in practice, while they both bring into effect the principle of action of the fuel which has long appeared to me to be the best that can be adopted for ordinary cases of steam-engine boilers.

I have now occupied, I think, enough of your time, and so I will conclude. I have endeavored to select out of the wide range of subjects which fall within the scope of the Mechanical Section of the British Association, a few which have come more particularly under my own notice, and on which I thought it was in my power to give intelligence that might be interesting as to past progress, and suggestions that might be useful towards extension of improvements in the future.

ON DIAMOND DRILLING.

By Chas. E. Ronaldson, M. E.

One of the most interesting, as well as important, improvements in ground or rock drilling, is the substitution of the diamond, as a cutter, in the place of steel, iron, etc. Ranking first on the scale of hardness, its durability being unsurpassed, it is thereby eminently fitted to take precedence of any mineral or metal which had ever been used up to the time when the idea of using the diamond for this purpose was conceived.

Since its introduction, many important improvements have been added, and though still in its infancy it bids fair at no distant period to play a very important part in every form of drilling, boring, and, maybe, turning. It admits of uses to which it has never been applied, but which it is merely a question of time to perfect, and to bring into practical use. Though diamonds are not inexpensive, yet the wonderful results accomplished by their use, prevent them from being considered too costly to be employed for their present use as cutters.

It was my pleasure, a short time since, to witness the drilling of a hole (at Delano, Schuylkill county, Pa.) for the purpose of ascertaining the existence of coal.

Upon the Delano Tract, and about two hundred yards from the position of the drill, two veins out-cropped upon one side of the hill; while upon the other side a tunnel is in progress, the hill being drilled to determine the distance the tunnel should be run to meet the veins.

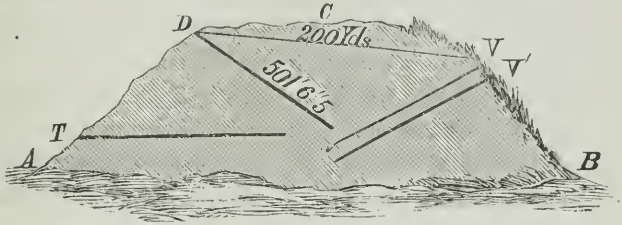

Fig. 1.

In the above Cut, Fig 1, A B C represents a Section of the Hill. T, is the location and direction of the Tunnel. D, the position of Drill, set at an angle of 60°. V V′ are the location and direction of the Coal Veins. A very peculiar fault, or displacement of the veins occurs, for by calculation, the hole should have struck them at a depth of not more than three hundred feet, whereas they reached a depth of 501 feet 6·5 inches, and found coal wanting, merely passing through a stratum of slate and bony coal one foot in thickness, which was supposed to be the Buck Mountain Vein, which vein is successfully worked less than one mile from here.

In drilling this hole, the general average worked was ten hours per day (including lost time), and the time worked amounted to 25 days and 5 hours, which was very quick work, when we consider the extreme hardness of the rock drilled through, being, in many places, strata almost pure quartz or silica. I heard of a hole drilled to 500 feet, which took three months to accomplish, having a double shift, and the rock comparatively soft.

The engine used at Delano was a "Root Square," of ten horse power, with Allison's, of Pottsville, patent cylinders. The average speed was 350 revolutions per minute. The average pressure upon the hydraulic feed was 100 pounds. The pressure in pump to flow the sediment was 120 pounds.

The various strata passed through are as follows, viz.:

No. of Stratum.		Thickness. Feet.	Thickness. Inches.
1	Fine conglomerate rock	10	4½
2	Coarse pebbled conglomerate	1	1½
3	Conglomerate (shade varying)	4	8
4	Fine conglomerate	7	8
5	Coarse pebbled conglomerate	4	9
6	Fine conglomerate	6	7
7	Conglomerate (varying)	23	8
8	Red conglomerate or oil rock	1	...
9	Sand slate	...	9
10	Coarse pebbled conglomerate	7	8
11	Conglomerate (varying)	9	4½
12	Sand slate	1	8
13	Coal slate	2	...
14	Coarse conglomerate	28	9½
15	Sand slate	...	6
16	Coarse conglomerate	2	...
17	Sand slate	3	8
18	Coarse conglomerate	15	6
19	Sand slate	3	6
20	Conglomerate (varying)	4	...
21	Sand slate	3	10
22	Flint quartz rock (*very hard*)	20	2
23	Conglomerate	6	6
24	Sand stone	5	2
25	Fine conglomerate	16	6
26	Coal slate	1	3
27	Sand stone	4	9
28	Coal slate	7	7
29	Sand stone	6	...
30	Soft slate	3	9½
31	Sand slate	3	...
32	Sand stone (7 foot vein)......[overlying the Buck Mt. Vein.	7	...
33	Hard slate	8	6
34	Coarse conglomerate	13	8
35	Sand stone	2	...
36	Coarse pebbled conglomerate	24	10½
37	Sand stone	1	...
38	Coarse conglomerate	29	3½
39	Slate (soft)	1	...
40	Coarse pebbled conglomerate	7	2
41	Hard slate	2	6
42	Coarse pebbled conglomerate	22	10½
43	Flint quartz conglomerate (very hard)	7	3¾
44	Conglomerate with seams of slate	...	6
45	Hard slate	...	3
46	Conglomerate (varying)	1	5
47	Fine grain conglomerate	3	...
48	Sand stone	2	8
49	Coarse pebbled conglomerate	10	10
50	Slate and bony coal (supposed Buck Mt. Vein)	1	...
51	Conglomerate (varying)	47	2
52	Sand rock	1	...
53	Coarse pebbled conglomerate	7	8
54	Blue conglomerate rock	11	½
55	Sand rock	1	4½
56	Seams of slate and sand stone	36	9½
57	Sandstone slate and seams of coal	1	2
58	Coarse pebbled conglomerate	18	6
59	Sandstone with seams of slate	3	...
60	Coarse pebbled conglomerate with seams of slate	14	...
61	Coarse conglomerate	7	6
62	Sand stone	...	6
63	Coarse conglomerate	...	7
		501	6.5

Possibly a brief description of the Core-barrel, Bits, Rods, etc., may be of interest, so we will begin with the

Core-barrel, which is a hollow cylinder of iron, 12 feet in length, with diamonds set upon the outside, three or four feet apart; to protect the barrel from wear, there is a groove (square) cut upon the outside similar to the thread of a screw; it is 1-16th of an inch deep, and allows a free passage for the water to the Bit upon the lower end. An inside thread is cut upon the upper end, to allow the insertion of the couplings, to connect it with the rods.

The *Bits* are made of solid steel, drilled, and contain generally ten diamonds. Those diamonds for cutting the outside clearance are generally the *Bort's*, being harder than the ordinary diamond, in order to keep the size of the bit. The Fall or *end* diamonds are the carbon. There are also a few diamonds placed up, upon the outside of the bit, to prevent wear. Four diamonds are generally used to cut the core and allow its free passage into the core-barrel.

The *Core-lifter* is separate from the bit, and contains upon the inside a loose ring, split on one side; the ring is turned tapering, and works upon an inclined plane, in this manner: When the bit is cutting, the core forces the ring up into the upper cavity or top of the incline, allowing the free passage of the core into the Barrel, but so soon as the motion is reversed, the core slipping back, the ring falls into the lower cavity of incline, and jams the core, holding it securely until it can be removed at the surface.

Rock cores have been taken out 12 feet in length, and one measuring that length (12 feet) was taken out by a Mr. Nash, near Pittston, Luzerne county, Pa., and is the longest yet taken out in this State. Mr. N. has also taken out the longest *Coal core*, it measuring 23 inches. The 12 feet core was of conglomerate rock.

Mr. Thomas Nash (a brother of the above), and having charge of the drilling at Delano, took out a piece of core 9 feet in length, of conglomerate rock.

The *Rods* are hollow cylinders of iron, a thread cut upon the inside of each end for a short distance, to allow the introduction of the Coupling, which is of iron, 6 inches long, with a ⅝ hole drilled in the direction of the length; they each weigh 2¼ pounds. The rods are 8 feet in length, and weigh 5 pounds to the foot; they are 1⅞ inches in diameter.

In drawing out the Rods they are disconnected at every 16 feet, and in order to prevent the remaining undrawn rods from slipping back into the hole, they are caught and securely held by what is known as the Safety Clamp, an ingenious invention of Mr. Bullock, Superintendent of the American Diamond Drill Company of New York.

The *Clamp* consists of a Strap, in which are two brasses, one of which works upon an incline plane, at an angle with the other. A set-screw at the back of the strap jams the brasses to the rod, and when the pressure is removed, or the screw loosened, a small spiral spring forces the opposite brass up the incline, and the pressure upon the rod being removed, it can be easily withdrawn.

The Core-barrel is Mr. Frisbie's invention, he being at present, Superintendent of the Pennsylvania Diamond Drill Company, of Pottsville, Pa. To this gentleman is attributed the success and perfection of the diamond drill, he having added many valuable improvements.

The bits are manufactured at Pottsville, Pa. Formerly only one cylinder was used in the hydraulic feed, but Mr. Allison has combined two, whereby an equal and uniform pressure and motion is given in feeding down the drill, which is a very valuable invention.

This article has been hurriedly written, but I trust it may be of interest to those who have no opportunity to witness the operation.

THE MANUFACTURE OF CAOUTCHOUC AND ITS INDUSTRIAL USES.*

By Eugene Pavoux,

Director of the General India-rubber Manufactory at Brussels.

The multifarious uses of india-rubber, and the numerous industries in which it is employed, are such as to give an interest to the consideration of the properties of this material and of the means employed to give it the appearance and the forms under which it is rendered useful.

Its principal quality is its elasticity at an ordinary temperature. This special quality, to which it owes its repute, disappears almost entirely under a temperature approaching to that of melting ice, and only reappears when the india-rubber is subjected to a heat of from 30° to 40° Cent., when it again becomes supple. It softens in proportion as the temperature rises, becomes viscous, and ends by taking the consistency of treacle. This sensibility to the influence of temperature must have prevented its being used in industrial pursuits, if means had not been found of neutralizing it by a special manufacturing operation. Above 200° it is decomposed, and passes off in a volatile form.

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Its density varies between 0·925 and 0·950. According to Faraday, it is composed of 87·2 of carbon and 12·8 of hydrogen.

India-rubber is a sap which flows from various sorts of trees which grow in abundance in the regions near to the equator, notably the *Ficus elastica*, the *Siphonia cahucha*, &c. Its qualities are distinguished by the places where it is grown, and sometimes, though rarely, by some external characteristic. The terms most frequently used in the manufacture are: Para, Madagascar, Carthagena, Guyaquil, Borneo, West India, Assam, &c. It is obtained as follows:

The trunk of the tree is pierced, and the sap (which contains about 40 per cent. of india-rubber) is allowed to run off into a vessel, but more frequently into a hole dug at the foot of the tree. Balls of dried clay made in the shape of pears are plunged into the liquid, and afterwards passed over a fire made of the branches of trees, in order that the layer of india-rubber which has been deposited on the clay may be made to coagulate rapidly. This operation is repeated until a certain thickness has been acquired. The balls are then plunged into water, and the clay, thus softened, is easily got rid of by simple pressure.

Sometimes a thin board is used as a nucleus, on which the sap is deposited and agglomerated; in this case, the mass of india-rubber thus collected is cut on three sides to admit of the board being drawn out, and in this way double sheets are obtained, which open almost in the same way as a book. The purest india-rubbers are those which are gathered in this way; such as Para and Madagascar, the simple aspect of which reveals the almost total absence of extraneous matter.

When the sap is allowed to run out on the ground, it collects in irregular strips, mixing with the impurities of the soil. These strips are put into sacks and sent off to the various places of consumption.

When they are very thin they are rolled up like a skein of thread, and the appearance of the india-rubber in balls serves to remind one of a clue of worsted.

In these different states india-rubber comes to Europe. It is indispensable to rid it of every kind of detritus, sand, wood, pebbles, bark, etc., which have become mixed with the gum whilst running from the tree. This is the object of the first process in the manufacture. The raw material, after being softened by immersion in a large tub of hot water, is cut up with a saw into cubic pieces of about an inch and a half, then flattened between two cylinders, placed horizontally, the distance between which is regulated at will by set-screws. These cylinders are of different velocities; it follows, therefore, that, independently of the pressure which the india-rubber is made to undergo, it is hacked and torn to such an extent that all extraneous matters are removed, and under the continuous action of a stream of water; they are easily carried off. Under this process, which is repeated eight or ten times, every time bringing the two cylinders nearer together, all the impurities vanish, and the rubber assumes the form of an irregular sheet, grained, and pierced through with innumerable holes. This sheet, when hung up to dry in a place where the air circulates freely, thanks to its texture, very soon loses the water with which it is impregnated.

It is important that the material should be kneaded, in order to bring together in a single piece the scattered elements of the sheet, and impart to it perfect homogeneity. This is done by means of a kneader called a "devil," which consists of a cylinder fixed horizontally, divided or not into separate compartments by partitions perpendicular to the axis. Over the total length of this cylinder, and a quarter of its circumference, there is an opening by a sort of door on hinges, through which the dried rubber is introduced. A shaft, provided with a series of sharp-pointed teeth disposed in rows alternating one with another, runs through the whole length of it. This shaft, which makes seven or eight revolutions a minute, carries along with it the grained sheet of which I have spoken, and causes it to traverse the entire free space of the cylinder. In doing this the mass of caoutchouc takes a rotating motion, produced by the teeth, which successively take it up and draw it towards them. There results from this a perfect process of trituration, which forms the sheet of rubber into a compact mass, all the parts of which are thoroughly mixed.

In order that this operation may be effected under proper conditions, it is necessary that the roll of caoutchouc which has to be put into the cylinder should be a little wider than the cylinder itself, in order that it may press against the sides, and, consequently, be regularly drawn in by the motion of the shaft. This proceeding lasts, on an average, a couple of hours; the longer it is continued, the less time is required for the process which has to follow, by reason of the thorough homogeneity into which the material has been brought.

The devil, as it is called, is usually formed with a double casing, which is heated by means of a steam jet.

I have been induced to abolish this, because I find that the heat developed by the work itself is sufficient to facilitate the kneading of the material, whilst if it is increased by that arising from the steam, the temperature is such as to cause the rubber to become soft and viscous, and this deteriorates its quality and interferes with the following operations.

On leaving the devil, the material passes to the compressing cylinders, which are placed in couples on a horizontal plane, and may be brought to any distance from each other by means of screws worked by a crank placed within the reach of the workman.

These cylinders are hollow, and are heated internally with steam by a pipe running through a packed box. Two pipes running into one serve to discharge the steam, the ingress and egress of which are regulated, according to the necessities of the work, by taps. The rubber is thus thoroughly compressed until it presents the aspect of a rolled-up sheet, of firm texture, close, and exceedingly smooth. This gives the finish to the preceding operations.

Pure india-rubber is only used for certain special purposes. The requirements of industry demand various qualities of products, possessing properties suitable to the different uses to which they are to be applied; it is the mixture of blocks of compressed rubber with foreign matters in certain proportions which enables the manufacturer to produce qualities answering to the variable conditions under which they have to be used. Rolling forms a mixture of these several substances, which is regular and uniform throughout; it is also during this operation that the coloring matter is added, which gives to india-rubber its various shades of gray, black, red, etc., in which it so frequently appears. It is in the form of powder that all these matters are mixed with it. At every passage between the cylinders a portion of it escapes, and falls on a slightly inclined table, which is gathered up by the workman and thrown again into the mass, which, becoming wider by the pressure, is rolled up by the workman as it issues from the cylinders, between which he puts it in afterwards lengthwise. It is, therefore, rolled in every possible way, which tends to give to the texture a greater degree of homogeneity.

The india-rubber paste obtained by this process is afterwards worked up either by rolling or moulding.

In the first case sheets are made of any length and thickness that may be required, whilst in the second it is cast in any mould the manufacturer may desire.

As regards the rolling, the paste is made to pass between the two cylinders of a calender, by which it is spread out into a sheet of the same dimensions as the cylinders; these sheets may be made to any length, of course, by feeding the calender continually with one block of material after the other. The adhesive tendency of india-rubber is so strong that when the finished sheet has to be wound on to a roller, it can only be done by the interposition of a piece of cloth, which serves to separate the different windings of the sheet. It is then placed on a table and unrolled, in order to be worked up into the form and dimensions required. The same calender serves for coating cloth, which is used for many purposes, amongst others, for making tubes and straps; the paste, which passes through the cylinders at the same time as the cloth, is spread upon it in a layer, the thickness of which is regulated by the distance, and the tenacity with which it sticks is in proportion to its adhesive qualities.

Certain pieces are suitable for special forms, which they can only be made to take by moulding. In order to manufacture these, the india-rubber paste is put into a mould, which is filled more or less exactly. The exposure of this mould to a temperature varying between 125° and 150° causes the material to expand and penetrate into every part of the mould, and to take the exact form that is wanted. If a hollow article is required, a little water is introduced, which, being changed into vapor by the heat, compresses the paste, and makes it adhere to the sides of the mould, of which it takes the exact outline.

There is one remark which it is important to make: it is that the paste adheres easily by simple contact, as long as the material has not undergone the process of vulcanization. The shape then (with the exception of the cutting of certain objects from sheets) should always be given previous to vulcanizing, which is the last process of manufacture.

Raw india-rubber seems to consist of two parts, each possessing distinct properties: the one compact and elastic, the other heavy and semi-liquid. It is to the presence of the latter element that is to be attributed the extreme facility of adhesion by which it is characterized, and it serves to explain the way it is affected by the action of the cold, and the modification it undergoes under the influence of a high temperature. The transformation of the viscous part, which is most sensitive to the variations of heat, has the effect of preventing those grave inconveniences arising out of it, and of making india-rubber a substance that can be utilized under any conceivable circumstances. That is the object attained by vulcanization.

The agent employed for vulcanizing is sulphur. Its action on india-rubber is analogous to that with which it acts on fatty substances which, when mixed with it in the proportion of one to five, and heated to a temperature of about 200°, produce a substance offering a good deal of resistance, and presenting almost the aspect of india-rubber. The result is that vulcanized rubber does not harden with the cold, neither does it soften with the heat; it preserves its elasticity, resists acids, and can no longer be made either to dissolve or to adhere.

The incorporation of sulphur is effected either in the solid state or in a state of fusion, according to the nature of the articles that have to be vulcanized. The first method, which is the most in use, consists in mixing flowers of sulphur with the rubber at the same time as the other matters which are added in rolling; it thus becomes uniformly mixed with the mass, but as the reaction to which it must give rise can only be produced at a high temperature, it does not so far modify the properties of the india-rubber paste, which still continues adhesive. The article which is being made is put into a boiler made of sheet-iron, capable of supporting a pressure equal to from four to five atmospheres, and closed by a bolted lid; a jet of steam is let in, the tension being measured by a steam gauge, and the length of time during which the operation continues varies according to the number of pieces, but it is estimated at a couple of hours on an average. The necessary temperature is about 150°. When it is required to put several objects one on the top of the other, they are sprinkled all over with silicate of magnesia to prevent them from adhering to their supports.

The articles manufactured in moulds with an open surface are vulcanized in presses composed to two hollow, horizontal plates, the uppermost of which is moveable, and worked by screws which allow it to work up and down. The moulds are placed between these two plates, and in this manner the paste is compressed. The necessary temperature is produced by the steam which circulates in them from pipes placed at one of the extremities, and passing at the other end through outlet pipes.

I have had fixed up in my manufactory a large press of this kind, by which I am enabled to vulcanize sheets, with great economy of time; the plates are about 7 feet long by 4 feet wide; their internal surface being carefully planed and dressed they give to the sheets a glossy appearance, with remarkable uniformity of character.

To produce vulcanization by the liquid method, the sulphur is put, in a state of fusion, into large boilers, underneath which are large fire-places; the articles already made are plunged into these boilers, care being taken to keep them covered with the liquid by means of weights. This precaution is indispensable, in consequence of the difference in density of the sulphur and the rubber. The absorption of the metalloid takes place, and is gradually completed until the combination is effected, which takes from two to three hours. Experience will be the best guide as to the time when the operation has been accomplished. Care must be taken that it is not continued too long, because in this case the rubber becomes hard and loses its elasticity. As soon as the articles are taken from the boiler, they should be plunged into cold water; this causes the layer of sulphur deposited on the surface to crack, after which it is easily removed by scraping.

It is as well to remark that only small objects admit of this method of vulcanization; those of larger size must undergo the first process.

There are also other methods of vulcanization which, although less applicable to industrial products, nevertheless deserve to be mentioned. Chloride of sulphur mixed with sulphide of carbon, in the proportion of one to fifty, will produce this result. When immersed in this compound, the rubber becomes impregnated in a few minutes, after which it is plunged into a reservoir of cold water: the object of this is to neutralize the effect which a too prolonged immersion would have upon the surface, which would be to vulcanize it too much. During the immersion, the mixture penetrates into the centre of the mass. It is only articles that are not very thick that can be subjected to this process.

. It is exactly the same as regards the process which consists in the use of alkaline sulphides; the operation lasts about four hours. In consequence of the restricted application of this method, it may be regarded as more theoretical than practical.

After vulcanization, the surface of the rubber sometimes presents slight efflorescences of sulphur; these are easily removed by washing with an alkaline solution.

To dissolve india-rubber, no better agent can be employed than sulphide of carbon, to which must be added 5 per cent. of anhydrous alcohol; a product is thus formed which, when subjected to evaporation, leaves a residuum of rubber possessing all its primitive qualities. It may also be dissolved by any of the essential oils, but the material which results from their evaporation is oily and viscous, so that their use has been entirely abandoned.

Before proceeding to treat of the industrial uses of india-rubber, it will be interesting to say a few words respecting indurated rubber, which constitutes a special branch of manufacture; independent of its restricted application to great industrial purposes, it is applied to the manufacture of a large number of objects of all shapes and dimensions, adapted to ordinary daily wants. The manufacture of indurated rubber may be disposed of in two words. The quantity of sulphur which is mixed with the paste is larger, and amounts, according to circumstances, to from 35 to 40 per cent., and the vulcanization is prolonged beyond the ordinary limits, the maximum being from six to seven hours. For great thicknesses, a longer time may be necessary, but this is an exception. The operation is a very delicate one, and demands a great deal of care to prevent the article being burnt, as it in that case would become worthless.

Indurated india-rubber is worked with the file, the saw, and the lathe, exactly like metals and other hard substances.

The applications of india-rubber to industrial purposes are exceedingly numerous, and are increasing daily. "Its elasticity, its tenacity, added to which, the property it possesses of being completely homogeneous and impermeable, recommend it for a vast number of uses in which it would be difficult to find a substitute."*

The various kinds of joints which are used for water pipes, gas pipes, and steam pipes, may be classed in several categories, and india-rubber is used in all of them. The flat washers for flange joints are made in various qualities of material, but most frequently by means of one or several cloths dipped in the paste, and intended to prevent the lateral extension which would take place in pressing the surfaces together, as well as by the heat, in the case of joints with steam at high pressure; the number of cloths depends upon the thickness of the washer. Instead of being parallel at the surface, the cloths are frequently disposed concentrically, and are placed at a distance from each other of from two to three millimeters. The same result may be obtained with felted india-rubber, that is to say, mixed with fibrous matter, such as woollen or cotton waste, etc., which by their resistance admit of greater tenacity, and cause the lateral extension to be less felt.

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* A. Stevart: "Results of Experiments in the Elasticity of Vulcanized India-Rubber."

In laying the flange pipes, it often happens that, through the negligence of the workman, the centre of the washer does not coincide with the axis of the pipe, and causes a projection in the inside. When this defect presents itself at the lower part of a steam pipe, it prevents the waste water from running off; it is better, therefore, to adopt the system in which the washer is kept in its place by a flange at one of the ends of the pipe; the play left between the two pipes admits of expansion, without causing any danger.

The washers with circular section which are used for joining the pipes are especially employed in the ingenious system of which M. Leon Somzé is the inventor. The washer is introduced by being rolled into the annular space between the two ends, called male and female, of the jointing pipes, and is kept by the conical form of the male end in a perfect state of compression.

In making Delperdanges' joints it is necessary to use a ring forming a band, which, placed on the flanges, which are close to each other, of two pipes, is compressed and kept in its place by an iron bridle, terminated with two claws, which are pressed and brought together by a bolt. A copper sheet keeps the rubber against the pipe, where the claws are. This system has been at work in the water distribution of Lille and Valenciennes. Lastly, certain joints are made by means of a cord, either round or square, made of india-rubber alone or of felted rubber, which is placed in a groove in the two surfaces which have to be joined. The compression of this cord hermetically closes the two ends of the pipes.

India-rubber is also largely employed in transport. On the railways, the buffers are furnished with a series of washers of rectangular shape about two inches in thickness, separated from each by sheet-iron plates, which allow each washer to be compressed singly, so that every advantage is derived from the characteristic property of the material. To allow the passage of the buffer rod, these washers are pierced in the centre with a hole, the diameter of which is larger than that of the plates, in order that the depression of the washer may not drive back the rubber against the rod. For the same reason, the sheet-iron plates are of larger diameter to prevent the rubber from being pressed back beyond their outer edge.

In the construction of passenger carriages, arched pieces are used, which, being fixed in the inside of the wainscoting of the doors, receive the shock of the glass windows as they are lowered, and preserve them from the breakage to which they would be exposed without this precaution.

In tramways, the springs are replaced by buffers, taking the form of two truncated cones, united by their bases; these buffers, placed between the box and the axles, weaken, by their elasticity, the jolting of the cars, and render the motion exceedingly smooth and gentle. The tenacity, strength, and duration of the springs depend on the proportion of foreign matter which the material contains; there ought to be only a small proportion, but a certain quantity is essential, in order to give them the requisite body and solidity. The use of these springs in the wagons belonging to mines and quarries would, undoubtedly, diminish the deterioration in the rolling stock by preventing the violent shocks which are frequently caused by the dilapidation of the roads.

India-rubber is also used for the outer rim of wheels for vehicles used in railway stations, large manufactories, entrepots, etc. In this case the metallic rim of the wheel takes the shape of a groove, in which the elastic band is embedded; the diameter of the latter is ordinarily calculated at four-fifths of that of the wheel.

Road locomotives appear to have acquired an increase of tractive power by the application of similar bandages. There is no vehicle, even down to the velocipede, which does not make use of this material, endowed as it is with so many precious qualities.

It enters largely into the construction of machines, and especially of pumps. The valves vary in form as well as in thickness; some are round, others are square or rectangular. The seat on which they rest has several apertures, they are thus supported otherwise than on their edges, which preserves them against the pressure. The metallic breastwork which forms the seat ought to present no projecting edge, which would enter into the material, and cause speedy deterioration. These valves are, for the most part, made of simple india-rubber, but sometimes cloth is put between to give them greater tenacity. The special circumstances under which they have to be employed will guide the maker in the selection.

Certain valves are composed of a simple metallic sphere, covered with india-rubber, which, being raised by the liquid, falls down again as the piston descends, on the orifice it is intended to close. In order that these valves may retain sufficient suppleness to admit of their hermetically closing the orifice, it is better that they should consist of a hollow india-rubber sphere, filled almost entirely with small shot.

An ingenious application of india-rubber is that which has been made by M. Field, in respect to a valve composed of two india-rubber discs slightly conical, and placed face to face. These discs are flat and pierced with a hole in the centre, but they are compressed, and made to assume a conical shape by metallic pieces in the interior. Their external edges are in contact with each other, and maintained thus by the pressure which is exercised on their outer faces. The principal merit of these valves is their perfect resistance to the strongest pressure; in fact, their action being exerted in every part at the same time, the lips of the valve are forced against each other, with an energy which is greatest when the pressure is strongest. Messrs. Whitley, of Leeds, have applied this valve to all kinds of pumps, for pumping either cold or warm water or other liquids at pressures rising as high as ten and even thirteen atmospheres.

The Perreaux valve is exclusively composed of india-rubber. The side gets gradually thinner until it comes to the sharp edge, which is split, and opens out a little under the pressure of the liquid; it closes again as soon as the piston begins to descend.

As regards pumps which are intended to pump acids, an india-rubber bucket is used, in which the rod of the piston is placed; these pieces are moulded.

Hydraulic press rings made of india-rubber replace advantageously those covered with leather, which are high in price. These rings are moulded in exactly the form required, and they are much more flexible than leather ones, even of the very best quality.

India-rubber pipes, by reason of the multiplicity of their uses, and the diversity of their composition, form an important branch of manufacture. Those that are used for gas, acids, etc., and have to bear only a feeble pressure, are made of pure rubber by simply rolling a strip of paste round a mandrel; the soldering is easily effected by contact merely, and is consolidated by the pressure of two small blades, worked by hand. To prevent the paste from adhering to the mandrel, care is taken to dust it over first with powdered talc. Sometimes several strips are placed on the top of the other, the number being determined by the thickness of the pipe which is being made.

When the tubes are intended to be subjected to a certain pressure, they are consolidated by the insertion of one or more layers of cloth, the cohesion of which prevents the swelling of the pipe, the wearing away of the sides, or their rupture under extraordinary pressure. These pipes are generally formed as follows: A round of india-rubber on the mandrel forms the first tube, over which a strip of cloth is rolled, done over with india-rubber by a calender; a fresh round of pure paste is followed by a second covering of cloth, and the operation is repeated according to the number of folds the pipe is intended to have: this number of folds depends on the diameter, and increases generally with it. The outer envelope is india-rubber. By increasing the rounds of cloth, we obtain pipes capable of resisting the strongest pressure.

When a liquid has to be pumped up, it is necessary to guard against the crushing of the pipe, which the atmospheric pressure would inevitably cause. For this purpose a spiral is used, made of galvanized iron or copper, which is either simply placed in the interior of the tube, or imbedded in the thick part of the rubber. Generally, the outer part of the tube is formed of coarse cloth, which serves as a protecting envelope, as these pipes are nearly always intended to be trailed on the ground; they are much used for fire engines and pumping engines.

All these kinds of tubes can only be vulcanized after they have been finished. They are placed on a vehicle which runs on rails, and run into a boiler 20 yards long, specially prepared for them.

I manufacture a particular kind of pipe, for which I have taken out a patent. It is made of tanned hemp, with an inside casing of india-rubber, and can be advantageously applied to a great number of uses. Being tanned, it is enabled to resist moisture, which has not the slightest effect upon it. It is much lighter than leather, consequently, in case of fire, a man can carry a much greater length, and can mount a ladder with it much more easily. The application of india-rubber sheets to the interior of these tubes prevents the infiltration of water into the pores of the tissue; it also prevents any loss of liquid, and protects them from injury. The resistance is very considerable; a diameter of 1¾ inches will bear a pressure of fifteen atmospheres, and one of $\frac{3}{4}$ inch will bear twice the amount of pressure. They are used for fire engines, for brewery funnels, water pipes, steam pipes, etc.

The ropes used for packing, which are made of cloth, done over with india-rubber, are made without core, that is to say, without any inner nucleus in pure rubber; they are generally used concurrently with hemp for furnishing stuffing-boxes, and with the best results; the flexibility of the hemp admits of the expansion of the rubber, and this, in its turn, corrects the want of compactness presented by textile fabrics.

Straps merit special notice. They are composed of a certain number of folds of cloth done over with rubber, alternating with layers of pure rubber. The number of folds, and, consequently, the thickness of the strap, is in proportion to its width: for this reason, when the width is above 10 centimetres, there are at least three folds; above 15 centimetres, four folds; and above 25 centimetres they have from five to seven folds. They are made of all lengths in a single piece, and are joined exactly like those in leather, They work as well in water as in places heated to a high temperature. Their use is becoming very general, for besides being less costly than those in leather, they adhere much better. It is important that the several cloths of which they are made should not slip one over the other, and they should be made to adhere firmly by the intermediate layers of rubber. This object is attained by their being vulcanized in the press.

India-rubber has been used for some time in covering metal rollers employed for sizeing and finishing cloth; woolen rollers are replaced by metal ones, which prevent the necessity for using paper or cotton for stuffing the inside of the dressing cylinder; it also does away with the use of linen or woolen cloth for the external covering of the roller, one or more sheets of india-rubber being now used instead. Manufacturers find great advantage in this. The size, whether colored or not, adheres sufficiently to the rubber to admit of either threads or tissues being well sized without any absorption of the material by the rubber; the size, therefore, as well as the coloring matter can be taken off the roller by simply washing it with water, which permits the immediate use of the same apparatus for sizeing in the other colors. The india-rubber covering, by adhering thoroughly to the metal, and having none of these protuberances caused by the crossing of linen or woolen covers, presents a perfectly smooth and regular surface, and gives greater uniformity to the sizeing.

The thickness of the covering varies from 12 to 15 millimetres, according to the diameter of the cylinder. To have it in good order, the surface of the cylinder should be perfectly smooth.

Billiard makers secure great elasticity for their side cushions by using india-rubber, to which they give various shapes at discretion. The material used for this purpose ought to have rather greater density than the raw rubber.

The other industrial uses to which it is applied are innumerable ; I need only mention the buckets and funnels used for acids, plugs with and without holes, rings and flanges for the joints of washing machines, rollers for twisting frames, sets of pulleys for ribbon saws, guide straps and aprons for paper-making machines, joints for filter presses used in sugar manufactories, moulds for hat manufacturers, aprons for sugar works, etc., etc.

As regards the application of indurated rubber, we may mention the rollers for spinning frames, made in two parts of different composition and color, the vulcanization of which is effected gradually, by means of a slow and progressive elevation of temperature, and lasts about four hours.

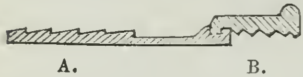
In telegraphy, insulating bells are used, suspended on hooks of galvanized iron. The outer surface is polished all over, and presents a thickness of 2½ millimetres, so as to cut off the electric current.

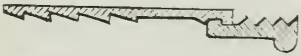
If I were to point out all the applications of india-rubber to surgery and ordinary uses, I should become involved in an endless nomenclature utterly at variance with the object of this brief memoir.

New Method for the Commercial Preparation of Oxygen.—Mr. J. A. Wanklyn of London, observing that copper oxide gave up easily its oxygen to barium oxide to produce barium peroxide, proposes to utilize this property in connection with the fact that metallic copper when highly heated, becomes oxidized to copper oxide, for the economical preparation of oxygen from atmospheric air. The barium oxide is mixed with at least half its weight of copper oxide, placed in an iron retort and heated to redness, a jet of steam being blown in. The barium peroxide at first formed gives up its oxygen, and becomes oxide again. Atmospheric air is then blown into the retort, (the steam being stopped) which again, through the mediation of the copper oxide, oxidizes the baryta to peroxide. This is then decomposed by steam, as before. Instead of baryta, caustic lime or manganic oxide may be used, or a mixture of the latter with lime or baryta.

New Hose Coupling.—Mr. R. Grimshaw has introduced a new hose coupling intended to preserve the butts of the hose, and constructed by a method which greatly reduces the cost.

In the ordinary hose coupling, the thimble or shank which passes through the hollow nut, has a flange against which the main portion of the nut presses when screwed up, but there is nothing to prevent the nut from sliding back against the hose when unscrewing, and thus injuring it. To prevent this, another flange has sometimes been placed behind the hollow nut and held in place by a pin or other contrivance, but this makes the coupling both heavy and costly.





In Mr. Grimshaw's method this thimble A is cast with two flanges upon it, forming a groove, which is nicely cleaned, or if necessary, turned smooth in the lathe. The surface of this groove is then coated with black wash, the thimble placed in a properly prepared mould, and the nut B cast around it, the flange of the latter being formed in the groove.

The black wash prevents contact of the molten metal with the metal of the thimble, and on being rubbed out, leaves sufficient clearance to allow the nut to turn freely.

Immense Photographs.—There is now on exhibition in Paris, says the *Revue Industrielle*, the two largest photographs which have been made since the introduction of the art. One of these photographs represents the principal facade of the new Opera, the other one of the bronzes—the Departure, by Rude—of the Arc de Triomphe de l'Etoile. Each of these prints measures 4 feet 3 inches in length and 3 feet 4 inches in height. They were obtained in one single piece, by well-known processes, and with the aid of a large and specially constructed camera. Except in some of the effects of perspective which perhaps are not reproduced with absolute fidelity, especially the portion representing the dome of the grand Opera, which appears, on the photographs, to crown the facade instead of being in a plane further back, all the lines of the pictures are of remarkable excellence; the mouldings, the busts, the medallions, the inscriptions and even the minutest details being reproduced with rare perfection. The attempt is being made to secure pictures even larger than this.

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EDITORIAL.

ITEMS AND NOVELTIES.

Planing of Metals.—The distinguished French Physicist and Engineer, M. Tresca, gives at the end of a long and elaborate memoir upon the planing of metals, recently published in the *Bulletin de la Société d' Encouragement*, the following exceedingly valuable conclusions :—

1. The operation of planing produces, in the prism of matter cut by the tool, characteristic pressures and deformations, which vary according to the form of the tool and the thickness of the prism removed.

2. These circumstances are more easy to define where the case is that of planing done over the whole breadth of a solid by means of a tool with a straight edge, and a cutting surface, plane or cylindrical, in which the generating lines are perpendicular to the direction of the movement, and parallel to the surface of the solid planed. With these conditions the shaving detached is a transformation of the original prism, produced by diminution of its length, in consequence of a transverse flowing (*ecoulement*) of matter in the direction of the thickness of the shaving, under pressure of the tool.

3. The co-efficient of longitudinal contraction depends on the degree of sharpness of the tool, the facilities it offers for disengagement

of the shaving, but, above all, the thickness of the shaving removed. The co-efficient of reduction is smaller for thin shavings, because the flowing in the transverse direction is then rendered easier.

4. The co-efficient of dilatation, in the thickness, is inversely as the co-efficient of reduction in the length.

5. The co-efficient of reduction varied, in the whole series of experiments made, from 0·10 to 0·60, and we possess shavings of steel of more than a millimetre in thickness, for which it does not exceed 0·25.

6. The surface of separation between the shaving and the block is always smooth, and is modeled on the cutting face of the tool. The opposite face is always striated, and presents the appearance of a series of parallel waves, which are more salient, the thicker the shaving. These waves continue to the edge, where we find indications of a flow in width, limited to a very small extent, commencing at these edges. In fine cuttings the striæ, which are much finer, impart a velvety appearance to the whole surface.

7. A circumference traced on the exterior face before planing is transformed into an ellipse, in which the relation of the two axes affords the measure of the co-efficient of reduction; but it is best to obtain it by operating with great lengths.

8. When the deformations exceed certain limits, the shaving is split at intervals, and there is a disjunction in the directions in which lie the furrows of the waves.

9. When the tool is blunted, the co-efficient of reduction diminishes, and the planing becomes more difficult.

10. The cylindrical form of the tool is very favorable to the operation, and an examination of the deformations leads us to the conclusion that the hyperbolic form is the most recommendable.

11. In virtue of the pressure exerted by the cutting face of the tool on that of the shaving, the latter emerges perpendicularly to the surface of the solid, thereupon turning round. Thin shavings become rolled up in the form of a cylinder with spiral base, the windings exactly covering each other. The radius of rolling increases with the thickness.

12. When the generating lines of the cylinder which forms the side of the cutting-face of the tool are inclined relatively to the plane of motion, the shaving, instead of being rolled up cylindrically, takes the form of the exterior surface of a screw with square thread.

13. The lateral attachment of a conical shaving by one or other of its edges has no sensible influence on the result of the planing. The co-efficient of reduction remains the same, but the edges originally engaged are less round, and are even cut sharply in one part of the thickness of the shaving.

14. When the dimension in thickness becomes comparable to the dimension in width, there is a dilatation in both directions, and the shaving takes a quite particular form, of triangular section, which is readily deduced from certain geometrical considerations.

15. The employment of a tool with a curved edge gives rise to similar transformations, which are explained in the same way.

16. From the geometrical point of view the formation of shavings may be represented in all its phases by geometrical traces, according to perfectly sure rules. In a first phase, that of driving back (*refoulement*), the matter not yet detached from the block, acquires, in each of its longitudinal sections, its definitive dimensions in thickness and width. In a second phase, that of flowing, the shaving slides on the face of the tool, and acquires its definitive section. In a last phase the shaving escapes, turning round, according as the co-efficients of reduction imposed on its different longitudinal sections exert on them an influence more or less preponderant.

17. With the rectangular tool, having equal angles, a shaving of square section is liberated in the bisector plane of the dihedral figure formed by the two faces removed, giving rise to a deformation more complex, but quite as plausible as that of ordinary shavings.

18. With the tool having a curved edge the effects are of the same order, and bring to light the mode of driving back of a solid brought to the state of fluidity under the action of the exterior pressures to which it is subjected on one of its faces. The gorge-curve, which is produced at the limit of the two first phases of the formation, is quite characteristic, and leaves its impress on the originally free face of the shaving, under the form of curved furrows, which are reproduced identically the same throughout the whole length.

19. In the shavings, the breadth is approximately determined by the chord which joins the extremities of the crescent detached at each passage of the edge.

20. The convexity of the shaving appears generally at the thicker border, and there is no exception to this, save in cases where the relative sharpness of the tool exerts, on the thin parts, an influence strong

enough to compensate that of the more favorable co-efficient of reduction corresponding to the thicker border.

21. The more complex kinds of planing, such as work with the lathe, on circumference or extremity, do not introduce any notable change into these conclusions; which are thus quite general.

22. The work necessary to produce planing is composed of a work of cutting and a work of deformation, each represented by rational formulæ.

23. These formulæ show the advantage of the thick passages (*passes*) which mark the present tendency in the industry of machine tools.

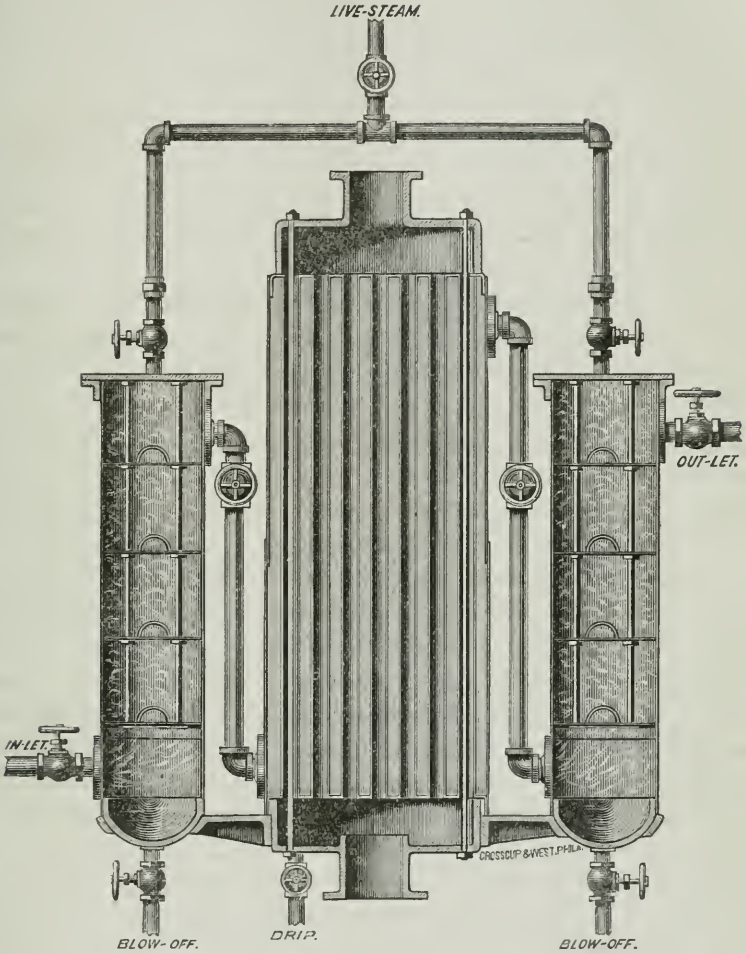
24. The pressure exerted by the tool is transmitted from transverse section to transverse section up to the limit of the zone of activity, according to a logarithmic law deduced from these formulæ.

25. Lastly, and it is the ruling character of this work, the hardest as the softest, metals are subjected in all these deformations to common laws which establish, for all the matter experimented with, an identity hardly suspected, hitherto, in their mechanical properties, even beyond their limit of elasticity.

26. The preceding effects are perhaps not without interest for the theory of the plough, which one may consider as a planing tool acting under special conditions.

Combined Feed-Water Heater and Filter.—At the stated meeting of the Institute for November, there was exhibited and described, the apparatus herewith illustrated, the invention of Mr. William T. Bate, of Conshohocken, Pa. The device is a combined feed-water heater and filter, and its purpose, as designed by the inventor, is to remove scale-producing and other impurities from feed-water for steam boilers, by forcing the feed-water, in its course towards the boiler, through an apparatus in which are combined a heater and cold and hot water filters.

The apparatus consists of the heater, which is a cylindrical iron vessel of adequate strength, provided with a series of tubes or passages to conduct the exhaust steam of the engine, and openings above and below, as shown in engraving. To the right and left of this heater, and communicating with it by pipes, are stationed the cold and hot water filters. These are duplicates of each other, and are provided with a series of perforated platforms, sustained in place by uprights. The object of this arrangement is to prevent the matting together of the filtering material, which would speedily take place were it left unsupported.



The operation of the device is about as follows: The feed-water is introduced into the lower portion of the cold water filter through the inlet, and is forced upwards through the successive sections of the filtering material (cotton-wool is usually employed), and is passed through the connecting pipe into the heater, having been deprived of the bulk of its mechanical impurities in its passage. In the heater, the feed-water has the heat of the exhaust steam imparted to it through the tubes, and is forced from the upper part of the vessel by a communicating pipe into the bottom of the second filter, where any residue of mechanical impurity, and doubtless some of its chemical impurities are retained. From the upper part of this filter, the feed-water, heated to a considerable degree, is passed by the outlet into the boiler.

The filtration, it will be observed, is upwards in both instances—the object of this being to prevent the rapid clogging of the filtering material; but this may, after becoming fouled, be thoroughly cleansed in a few minutes, by forcing live steam through it. For this purpose each filter is provided with live steam inlet and outlet pipes, the cocks in which are opened after closing those in the water pipes leading to and from the filters. The object of leading the water through a filter, before it enters the heater, is to prevent the latter from becoming inefficient by the deposit of mud, etc., upon the tubes. W.

The Altitude at which Men can live.—There has been a great deal of discussion, says *Chambers' Journal*, as to the altitude at which human beings can exist, and Mr. Glaisher himself can tell us as much about it as anybody. In July, 1872, he and Mr. Coxwell ascended in a balloon to the enormous height of 38,000 feet. Previous to the start, Mr. Glaisher's pulse stood at 76 beats a minute, Mr. Coxwell's at 74. At 17,000 feet, the pulse of the former was at 84, that of the latter, at 100. At 19,000 feet, Glaisher's hands and lips were quite blue, but not his face. At 21,000 feet, he heard his heart beating and his breathing became oppressed. At 29,000 feet, he became senseless; notwithstanding which the aeronaut in the interest of science, went up another 8,000 feet till he could no longer use his hands, and had to pull the strings of the valve with his teeth. Aeronauts, who have no exertions to make, have, of course, a great advantage over members of the Alpine Club and those who trust their legs; even at 13,000 feet these climbers feel very uncomfortable, more so in the Alps it seems than elsewhere. At the monastery of St. Bernard, 8,117 feet high, the monks become asthmatic, and are compelled to descend frequently into the Valley of the Rhone for—anything but a breath of fresh air; and at the end of ten years' service, are obliged to give up their high living and come down to their usual level. At the same time in South America there are towns such as Potosi, placed as high as the top of Mont Blanc, the inhabitants of which feel no inconvenience. The highest inhabited spot in the world, however, is the Buddhist Cloister of Hanle in Thibet, where twenty-one priests live at an altitude of 16,000 feet. The brothers Schlagintweit, when they explored the glaciers of the Ibi-Gamin in the same country, encamped at 21,000 feet, the highest altitude at which a European ever passed the night. Even at the top of Mt. Blanc, Professor Tyndall's guides found it very unpleasant to do this, although the Professor himself did not confess to feeling as bad as they. The highest mountain in the world is Mount Everest, in the Himalaya, 29,000 feet, and the condor has been seen "winging the blue air" 500 feet higher. The air, by the by, is not "blue," or else, as De Saussure pointed out, "the distant mountains which are covered with snow, would appear blue also;" its apparent color being due to the reflection of light.

Fatty Matter in Feed-Water of Boilers.—It is known that a quantity of fatty matter in the feed-water of a boiler causes a deposit which is not wet by water, and that this may lead to destruction of the boiler, inasmuch as the part of boiler side under the incrustation becomes more heated than other parts, and is apt to occasion rupture. A case of this kind, observed by M. Birnbaum, of Carlsruhe, has formed the subject of an investigation which he describes in a recent number of Dingler's *Polytechnisches Journal.*

The boiler in question had become leaky about two months after working had commenced, and most likely from a cause like that indicated, the incrusted boiler plates getting heated, and being bellied out by the steam pressure; when the boiler cooled, the metal sought to right itself, and thereby a force was developed, sufficient to tear the rivet holes

In the boiler there was found, besides a paper-thick coating of the usual deposit over the whole surface that was under water, a layer (from 2 to 3 mm. thick) of pulverulent matter, on the foremost half of the boiler bottom, which was a little inclined towards the fireplace. This powder was found very difficult to wet with water. Analysis showed that the incrustation contained a soap not soluble in water; there was at least 6 per cent. fatty acid present in the form of an insoluble soap. This fatty acid must have been neutralized by a certain quantity of lime or magnesia; and, to determine this, a quantitative analysis of the deposit was made. The result was:—Matter insoluble in muriatic acid (mud, sand), 16·83 per cent.; oxide of iron, 10·68; lime, 29·28; magnesia, 9·01; carbonic acid, 21·78; organic matter, 9·47; water, 2·77; total, 99·82 per cent. There was also present a small quantity of sulphuric acid, which could not be quantitatively determined. If we suppose the whole of the carbonic acid combined with lime, this will take 27·72 per cent. of lime, so that 1·56 per cent. lime and 9·05 per cent. magnesia remain available for neutralization of the fatty acid (which is included in the organic matter in the above analysis). With the proviso that the fatty acid was mainly oleic acid the 1·56 per cent. lime would more than suffice to neutralize the acid; a portion of the alkaline earths must thus have been free, perhaps in the form of a basic carbonate, in the deposit. It appeared, at all events, from this analysis that the powder contained at least 7 to 8 per cent. of an insoluble soap.

A further point to determine was whence the fat of this soap had come into the boiler. On examination it appeared that the spring water used for feeding the boiler was peculiarly adapted for this. The water, however, was previously heated in a heater, by waste steam entering it directly from the engine. Through the introduction of this steam the water was diluted, then distilled water was added, so that the water from the heater might give less deposit than the spring water. But in addition to the pure water condensed from the steam, other matters were introduced in the heater, which conduced to increase the precipitation of deposit. These were partly of an inorganic, partly of an organic nature. Among the inorganic matters must especially be mentioned hydrated oxide of iron. It could not but be that through action of air and carbonic acid of the spring water, the iron sides of the heater should have been covered with rust, which should afterwards be dissolved and transferred to the water. The iron rust was, however, only suspended in the water ; filtered water of the heater contained no iron. The quantity of organic matters introduced into the water by the steam was not insignificant. These also are not soluble in water ; filtered water of the heater contained a less quantity of organic matter than the spring water. The water out of the heater was directly examined for fat and soap, and out of 6 litres water 0.017 gram isolated fatty acid was obtained. With a still larger quantity the filtered water was quite free from soap, while the unfiltered showed a quantity of insoluble soap. Thus it appeared that the spring water, through contact with steam, took up fatty matter in the heater; this fat formed a soap insoluble in water, suspended in the water along with hydrated oxide of iron. Volatile fatty acids, *e. g.*, butyric acid, which, in similar cases, have sometimes been found in feed water, were not observed by M. Birnbaum.

It follows as a practical result of this investigation, that the water in the heater should not be brought into direct contact with the waste steam. It is more rational to send the steam through pipes, over which the feed-water is made to pass. If the steam be sent direct into the water, in the heater, the danger arising from presence of fatty matter may be so far diminished by filtration of the feed-water. —*Iron.*

Cutting Steel Rails Cold.—The cutting of a file in halves with soft iron was an old lecture experiment. The soft iron formed a disc about six inches in diameter, mounted on a lathe-spindle and run at about 2000 revolutions per minute. A file held to the edge of the disc was cut in two in about ten or fifteen seconds, the disc being unharmed. The shower of sparks rendered this a brilliant experiment very popular with a general audience. The principle involved, says the *Engineer*, is now being applied to a practical purpose. Mr. Charles White, Manager at Sir J. Brown & Co.'s Works, Sheffield, has found the cost of cutting off the ends of steel rails cold, in the ordinary way, so enormous, that he resolved to try another expedient. For experiment, he had an ordinary rail-saw put in the lathe and all the teeth cut off. The revolving disc was then mounted on a spindle and driven at nearly 3000 revolutions a minute. The disc was three feet in diameter, so that its circumferential velocity was about 27,000 feet, or over five miles a minute, or 300 miles an hour. Steel rails forced against the edge of this disc were easily cut through in three or four minutes each. The rails weighed 65 pounds to the yard. Sparks flew in abundance, and the disc appeared to melt the rail before it; but after cutting five rails the disc itself was not sensibly warm. The experiment was such a complete success that the firm intend putting up a very powerful saw for the purpose of cutting cold steel rails.

The Pyrophone.—A novel and very remarkable musical instrument has recently been invented by M. F. Kastner, of Paris, which, it is said, produces astonishing effects even in the midst of the largest orchestras. It is termed by its inventor the pyrophone. The origin of the device is due to a curious discovery made by M. Kastner in the properties of singing flames. Many scientific men have studied these interesting phenomena, but the peculiarities of two flames in conjunction seems to have escaped their notice. As a result of his investigation, M. Kastner finds that if, in a tube of glass or other suitable material, two or more isolated flames of proper size be introduced and located at a point corresponding to one-third the length of the tube, reckoning from the base, such flames will vibrate in unison. The phenomenon continues as long as the flames remain separate, but the sound ceases the instant they are brought in contact.

The pyrophone, at first sight, resembles an organ; but instead of being operated by air blown in, it produces its notes by the singing of the flames within the tubes, the quality of the sound, its pitch and intensity, depending, of course, on the dimensions of the latter. The burners from which the flames emerge are so arranged that the flames run together, but may be separated instantly by pressing down a key on an ordinary key-board in front. The position of the key in relation to the sound is the same as upon the piano or organ. According to the law above cited, as soon as a key is pressed the separated flames in the corresponding tube give forth a note, continuing, as in the organ, as long as the key is held down. It is said that the music thus produced is extremely beautiful, and that the sound closely resembles, in delicacy and purity, that of the human voice. The invention was patented in England last year (No. 1091), and is thus described in the specification:

The construction of this new or improved musical instrument, named the pyrophone, is based upon the musical instrument known as the chemical harmonicon.

It is well known that when a pure hydrogen gas-jet burns in a glass or china tube, or other vibrating material, a pleasant soft tone or sound is produced. The characteristic novelty of this improved instrument consists in the construction of the burners, and in the combined apparatus employed to act on these burners by means of the touch on the keys, similar to an ordinary piano, in order to obtain the sound or note required, or to stop it as required.

The burners are constructed with double oscillating branches or arms, in such manner that the two jets are brought into one by the contact of the two branches, while at the moment the sound or note is produced the two branches are separated, and form two distinct jets, which produce the vibration in the glass, china, or other tube which surrounds the branches of each jet or burner.

The improvements in the construction of the pyrophone consist—1. In dispensing with the inlet cock for the gas. 2. In the means employed for dispensing with the two cocks heretofore employed for regulating the passage of the gas to the two branches of each tube. 3. In a more simple arrangement of mechanism for transmitting the movement of each key to its two corresponding branches.—*London Journal of Gas-Lighting.*

New Light of Intense Photographic Power.—MM. Delachanal and Mermet have recently presented to the French Academy a description of a new light of very great photographic intensity. The dazzling combustion of nitric oxide gas, after agitation with a few drops of carbon disulphide, is well-known. The authors have sought to utilize this light photographically by making it continuous. The lamp which they employ for this purpose is very simple in its construction, consisting only of a pint bottle having two openings through the cork, and filled with fragments of some porous substance, such as sponge, coke, or better, pumice, for the purpose of imbibing the carbon disulphide. Through one opening in the cork passes a tube which reaches to within a quarter of an inch of the bottom; through the other passes a considerably larger tube, about eight inches long. This latter tube may be of glass or of metal, and is closely packed with iron-scale. This is intended to act like the gauze in the safety-lamp, and to prevent the return of the flame into the bottle and its consequent explosion. The nitric oxide gas is passed into the bottle through the former tube above mentioned, and the gaseous mixture is conducted by a rubber tube to a kind of Bunsen burner, the air-holes of which are closed, and which is furnished with a small conical valve to regulate the flow of gas. This burner is also filled with iron-scale.

The nitric oxide gas is produced in the cold by the large apparatus of Sainte-Claire Deville, by the action of a mixture, in certain proportions, of nitric and sulphuric acids upon metallic iron. In one gas bottle, upon a layer of fragments of porcelain, the iron, in small bars, is placed; the other gas bottle is filled with the mixture of acids. The two are connected by a large rubber tube attached to the two tubulures near the bottom. The cork of the gas bottle containing the iron has a cock passing through it, to regulate the delivery of the gas. With an apparatus of quite moderate dimensions, a dazzling flame, measuring not less than ten inches in height, can be obtained, abundantly sufficient for the purpose of photographic work.

Among the experiments made in the laboratory of M. Franck de Villecholle, the photographer, the authors give the following: The lamp above mentioned used to illuminate the dark room was placed about six feet distant from an engraving; in five seconds, without using any lens or mirror to condense the light, an excellent negative was obtained. A portrait of the photographer himself, placed at the same distance and under the same conditions, was obtained in fourteen seconds. In these experiments the products of combustion, sulphurous and carbonic gases, were conducted into the chimney, because otherwise they would annoy the sitter.

M. Franck estimates that the photographic power of the lamp is superior to that of magnesium, is twice as great as that of the oxyhydrogen light, and three times as great as that of the electric light. Moreover, the flame which it gives is absolutely steady, and there is no fear of its sudden extinction, as there is with magnesium. The extent of surface of the flame permits the illumination of large surfaces, and the eyes can support its brilliance without being in the least affected. Finally, its cost is much less than that of either of the other lights.

These advantages lead the inventors to expect the practical introduction of the nitro-sulphide lamp, especially for photographic enlargements and reproductions, as well as for the reproduction of microscopic objects.

On examining this light by means of a spectroscope consisting of four prisms, a banded spectrum was obtained consisting of a series of brilliant lines close together. The inventors are now occupied with experiments to test the question whether this light, like that of magnesium and that produced by electricity, has the power of developing the green coloring matter of leaves.

Restoring Old Files.—M. Werderman has patented the following process for re-sharpening old files which have become useless by long wear: After thorough washing with a strong and hot solution of caustic soda, the files are put in connection with the positive electrode of a battery and plunged into a bath composed of 40 parts of sulphuric acid and 1000 parts of water. The negative electrode consists of a copper wire spiral surrounding but not touching the files, the end of the wire coming to the surface to be connected with the battery. After ten minutes of immersion, the files are withdrawn, washed, dried, and examined; if the cut is not sufficiently deep, they are replaced in the bath. Sometimes two operations are required, but rarely more. Files thus treated have, it is said, the appearance of new ones, and may be used constantly for sixty hours without losing their cutting power. The battery employed by M. Werderman is twelve Bunsen cells.

Franklin Institute.

HALL OF THE INSTITUTE, Nov. 18th, 1874.

The meeting was called to order at the usual hour, with the Vice President, Dr. Robert E. Rogers, in the Chair.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at their stated meeting, held on the 11th instant, the following donations to the Library were reported, to wit:

Annales des Ponts et Chaussées, for June, 1874. Paris. From the Editor.

Report of a Tour of Inspection of European Light House Establishments, made in 1873, by Major George H. Elliott. Washington, 1874. From the Author.

Report of the Investigating Committee of the Pennsylvania Railroad Company. Philadelphia, 1874. From the Company.

Annual Report of the Board of Regents of the Smithsonian Instistitution, for the year 1871. From the Smithsonian Institution.

Same, for the year 1872. From the same.

Smithsonian Miscellaneous Collections. Vols. 10, 11, 12. From the same.

Smithsonian Contributions to Knowledge. Vol. 19. From the same.

Chief Engineer's Monthly Report of the Manchester Steam Users' Association. July, August, 1874. From the Association.

British Patent Reports; with Index of Patents and Patentees, for 1871; and Statistical Tablet relating to the Colony of Victoria. London. From the Hon. Commissioner of Patents, and William H. Archer, Registrar General of Victoria.

Abridgements of Specifications relating to Safes, Strong Rooms, Tills, and similar repositories. 1801–1866. London, 1874. From the Hon. Commissioner of Patents.

Agricultural Report for 1872. Washington, 1874. From the Hon. Commissioner of Agriculture.

Les Chemins de Fer Anglais, en 1873. Par E. Malezieux. Paris, 1874. From the Author.

Proceedings of the Academy of Natural Sciences of Philadelphia. April to September, 1874. From the Academy.

Logarithms of Sines and Cosines, etc. Washington, 1874. From the Bureau of Navigation.

Geological Survey of Canada. Report of Progress. 1872–73. From the Director.

Technical Training. By Thomas Twining. From the Author.

Bulletin de la Société d'Encouragement. Vol. I., No. 8, 1874. Paris. From the Society.

Annales de Chimie et de Physique. July—August, 1874. Paris. From the Editor.

Verhandlungen der K. K. Geologischen Reichsanstalt, No. 7, 1874. Vienna. From the Director.

Jahrbuch derselben. Vol. 14, April to June, 1874. From the same.

Uber die Triadischen Pelecypoden, Gattungen, Daonella und Halobia. By Dr. E. M. v. Mojsvar. From the same.

Uber die Palaeozoischen Gebilde Podoliens and deren Versteinerungen. By Dr. Alois v. Alth. From the same.

The presiding officer next called upon Mr. William P. Tatham, Chairman of the Committee on Exhibition, who responded by stating that thus far the time had been insufficient to permit of a written report upon the late Exhibition, and he would therefore content himself with a verbal account of its history and results. He thereupon proceeded to give a historical sketch of the event, from its first suggestion, by Mr. J. Morgan Eldridge, to its close, recounting the manner in which the Institute obtained the use of the Freight Depot from the Pennsylvania Railroad Company, the raising of the guarantee fund, the enlargement of the Standing Committee on Exhibition to 100, the formation of the several sub-committees on rules, buildings, and machinery, space, transportation, correspondence, etc., paying a high compliment to the chairmen and members of these sub-committees for their untiring devotion to the arduous labors that devolved upon them, and especially to the energy and tact of the Superintendent of the Exhibition, Mr. J. B. Knight. The exact financial results of the event, he furthermore stated, it was at this time impossible to know, but it would, without doubt, be quite favorable.

Mr. Hector Orr followed with some remarks, in which he congratulated the Committee and the Institute upon the success of the late Exhibition.

Mr. J. W. Nystrom then presented a paper entitled the "Progress and Future of the Franklin Institute," in which the author, after alluding to the very wide-spread public interest in the affairs of the Institute, which the late Exhibition had undoubtedly created, urged for the proper advancement of its objects, that measures be set on foot to obtain the ownership of the lot upon which the Exhibition was held, upon which suitable buildings could be erected in time, in which the business of the Institute and its future Exhibitions could be held. The speaker urged that the Institute should be developed into an organization analogous to the South Kensington Museum in London, *i. e.*, with a technical school for the thorough training of mechanics and others in various branches of the useful arts, and exhibitions of arts and manufactures at stated periods. To realize this scheme in practice, the author contended, the Institute could confidently rely upon the liberality of its members, and their public spirited fellow-citizens, and likewise upon the legislature of the State. He concluded by offering the following preamble and resolution:

"WHEREAS, The Franklin Institute desires to maintain the lead in the promotion of the Mechanic Arts in this country, and

"*Whereas*, The proper performance of this high function transcends its present resources and accommodations; be it therefore

"*Resolved,* That a committee be appointed to inquire into the feasibility of securing a spacious lot in the centre of Philadelphia, for the purpose of erecting thereon a large and commodious building for the Franklin Institute and its future Exhibitions."

The presiding officer explained that the discussion of the resolution would properly be in place under the head of new business, and declared the postponement of the subject until that order of business was reached.

The Secretary's Report was next offered, which, besides a number of items of Engineering progress, included a description, illustrated upon the screen, of Mr. Wm. T. Bate's (of Conshohocken, Pa.) Combined Feed-Water Heater and Filter, and an exhibition of some samples of asbestos board, made by Mr. Rosenthal, of Philadelphia.

The discussion of Mr. Nystrom's resolution came next in order. The mover made some remarks in behalf of his motion, and was followed by Mr. Orr, in the same strain, who urged that if the public were made aware of the fact that the Institute was making an earnest effort of the character contemplated in the resolution, the necessary pecuniary aid would be forthcoming.

Mr. Lippman urged the erection of a large building upon an appropriate site, the cost to be defrayed by the issuance of interest bearing bonds.

Mr. Charles S. Close earnestly opposed the project at the present time as inexpedient, and reminded its advocates of a former unfortunate speculation of this description that had crippled the usefulness of the Institute for years. If the money could be obtained wherewith to realize the project, he would certainly favor it, but he was utterly opposed to running the Institute into debt.

Dr. Rogers resigned the Chair to Mr. Orr, and took the floor, making a strong address endorsing the remarks just made by Mr. Close. He added thereto, that he did not deem an annual exhibition desirable.

Mr. Alexander Barry remarked, that in a few years, there would be a vast building in Fairmount Park, which the Institute might, in all probability, make use of for exhibition purposes whenever it desired.

Mr. G. Morgan Eldridge favored the resolution.

The resolution was thereupon put to the meeting, and was carried.

It was further decided that the committee should be five in number, the names to be announced at the next meeting.

Dr. Rogers spoke in flattering terms of the liberal action of the Pennsylvania Railroad Company, and of the obligation under which the Institute rested.

Mr. Orr thereupon moved that a committee be appointed by the Chair, to draft a testimonial expressive of the sense entertained by the Institute of its obligations to the Pennsylvania Railroad Company, for its liberal action in granting the use of its Freight Depot for the late Exhibition.

The motion was carried; and the Chairman, at the suggestion of the meeting, appointed Messrs. Close, Knight, Orr, Rogers (Ch'n.), Sellers (Coleman), and Tatham as members of that committee.

The meeting then adjourned.

William H. Wahl, *Secretary.*

Civil and Mechanical Engineering.

ON THE METHODS OF TESTING STEAM ENGINES;

With a Description of the Trials of the Circulating Pumps on the U. S. S. "Tennessee."

By Geo. P. Hunt, P. A. Eng. U. S. Navy,
and
Theron Skeel, C. E., Morgan Iron Works, New York.

It has been generally customary, in making experiments on steam engines in order to determine their economy, to measure the amount of coal consumed in performing a certain amount of work. These measurements give the commercial economy of the machine.

So long as all the machines compared are of the same design and dimensions, and the coal used is of the same kind and quality, and the pressure of the steam, the degree of vacuum, the rate of expansion, the temperature of the atmosphere, and all other circumstances are the same, it may be inferred that any difference in the economy is the result of some imperfection in the machine itself.

Or if there is a variation in one particular only, as, for example, in the pressure of the steam, the difference may be fairly assumed to be due to that variation; but if there are several variations at the same time, as, for instance, different kinds of engines or boilers, and different steam pressures, when there is any gain or loss of economy it is impossible to decide to which of the variations the change is due.

It may be that if a poorer economy shows in the case where there is used the higher steam pressure and greater expansion, then the power which was gained by the high steam pressure and great expansion, was lost, together with something more, in the increased condensation and leakage; or that where in addition there are also used different kinds of boilers in the two cases, that the power which was gained in the engine was lost in the boiler, or the reverse, leaving the final result the same.

Any differences in the kinds of coal used, or in the skill of the firemen, blend themselves inseparably with the other variations, and are indistinguishable from them in the final result.

An exhaustive series of experiments on all of even the important points of variation in modern steam enginery, *separately*, there only being one variation in each experiment, would, even if practicable, take too long time and cost too much money to be even considered by any but a national power. Such experiments must be conducted on nearly the same sized machinery as that to which the results deduced are to be applied.

In attempting to compare the results of such experiments as he may find recorded, to determine the most economical design, the engineer finds that the experiments made especially for the determination of one certain point are generally not complete enough to serve any other purpose, and, in addition, that the experiments have generally been made by different observers under widely different circumstances and in widely separated localities; and, further, that the observer is almost invariably warped by some force, not necessarily of interest, but of opinion, to deceive even himself as to the actual conditions.

This last applies particularly to the reports which may be obtained from any new machine in the commercial world. For example, a steamship company substitutes in the place of an old ship of poor model, with old and nearly worn out engines and boilers, a new ship of greater capacity, finer lines, with new and improved machinery and boilers. They find by comparison of their accounts at the end of the year that the profits of the new ship are largely in excess of the old.

The engineer cannot separate the gain due to the increased size and improved model from that due to the improved machinery, much less the portion due to any particular variation from that due to the whole combination. If he would proceed surely to accomplish the same result he can only blindly copy the whole, unable to distinguish the good from the bad.

According to the dynamic theory of heat a certain weight of coal contains within itself a certain amount of work stored up, and ready to rush out under the necessary surroundings, as in the case of a compressed spring set free. The supply of a given weight of coal to the furnace of a steam boiler represents the application of a definite amount of force at one end of a series of transformations, a part of which force at length appears as useful work at the other, the balance having been wasted in the various processes through which it has passed.

Take, for example, a modern marine engine of the best construction and design. The force supplied to the furnace in the combustible is first developed as heat by the burning of the coal; a portion of this heat is utilized in changing the water into steam, the balance being wasted either in radiation or by being carried off in the hot gases through the chimney. A part of the steam formed is applied to move the piston, the balance being wasted by condensation against the sides of the pipes and cylinders, and by leakage past the piston or valves into the condenser. Only a small portion of the total force contained in the steam that is applied to move the piston is utilized, the balance escaping with the exhaust steam into the condenser. Of the force that is utilized in the cylinder only a portion performs any external work, the balance being absorbed in overcoming the back pressure and by the friction of the machine itself. Of the remaining small portion that may be applied to the screw another part is wasted in overcoming its useless resistances, and only the balance used to propel the ship.

The following figures represent approximately the *supposed* distribution of the total force in the best examples. No account is taken in them of the coal that is consumed in the various ways on board ship other than those mentioned, as, for instance, in getting up steam, for steam used to work pumps, for steam lost through the safety valves, for heat lost in blowing off, or remaining in the furnaces after the vessel has arrived in port. These and other causes usually add at least ten per cent. to the consumption, leaving the force utilized about *six* per cent. of the total force expended in the coal. The cost of an indicated horse power by the figures would be 2½ lbs. of coal per hour, nearly.

		PER CENT.
Total heat in one hundred lbs. of anthracite combustible, in units of heat,	1,400,000	
Deduct heat equivalent to weight of ashes,	200,000	
Total heat in one hundred lbs. of anthracite coal,	1,200,000	100
Carried off by hot gases in chimney,	200,000	16⅔
Available to produce steam,	1,000,000	83⅓
Lost by leakage and condensation,	200,000	16⅔
Available to perform work in cylinder,	800,000	66⅓
Escaped with steam into condenser,	660,000	55
Transformed into work,	140,000	11⅔
Absorbed in overcoming resistance of engine and load,	40,000	3⅓

		PER CENT.
Available to turn the propeller, . .	100,000	$8\frac{1}{3}$
Absorbed in useless resistances of screw or other propeller, ...	20,000	$1\frac{2}{3}$
Usefully applied to propel the ship, . .	80,000	$6\frac{2}{3}$

The owner of the ship only notices the first and last of these quantities, that is the amount of coal he has to pay for and the speed of his ship. The engineer may notice the amount of coal consumed and the indicated horse-power. They must, however, both remain in ignorance, without further experiment, of all the intermediate steps; steps by which at least 93 per cent. in the best cases, and 97 per cent. in the worst cases of the power supplied disappears.

The total amount of coal furnished may represent the amount of produce handled by a merchant to yield him a profit of six per cent. Would any man in any other case be satisfied with a system of accounts in his business which would leave him in ignorance of every thing but the gross outlay and the profits? We think not.

The actual amount of heat lost in each of the foregoing steps may be, with proper although inexpensive apparatus, measured for any practical case. That is, one may measure separately:—

1. The heat wasted in the chimney.
2. The heat lost by leakage or condensation.
3. The heat rejected with the exhaust steam.
4. The heat absorbed by overcoming friction and back pressure.
5. The heat lost by the inefficient action of the screw.

The first loss may be and has been measured in cases where the boilers furnished dry steam, by measuring the weight of water evaporated by a known weight of combustible, the water being measured in tanks, and the coal and water weighed. Knowing from former experiments the weight of water which would have been evaporated, if all the heat in the coal had been utilized, the difference between this and the weight actually evaporated is the portion lost, including both that lost from incomplete combustion and carried away in the hot gas and radiation. The quantity measured by the tanks would be the heat in the water corresponding to the number 1,000,000; and the heat lost to the number 200,000 in the example.

The second loss may be measured by subtracting the sum of the weight of steam delivered into the condenser, computed from the indicator cards and that condensed for the work done from the weight of feed water supplied. The difference corresponds to the number 200,000 in the sixth line of the example.

The second loss may also be actually measured where the engines are furnished with surface condensers, by measuring the amount of condensing water, and computing the weight of steam necessarily condensed in the condenser to raise its temperature from the temperature of the injection to that of the discharge.

This method has the advantage of being an independent measurement, and also that a comparison of the feed water computed in this way with that measured in the tanks will show a true result whether the boilers are priming or not.

Having been assured that the boilers will furnish dry steam, the tanks for the measurement of the feed water may be dispensed with, without causing serious error in the deductions; for as the same water is used for steam over and over again, and as the only water that can leave the boiler must be in the shape of steam, either that steam must be condensed *en route* from the boiler to the condenser or in the condenser.

When the tanks for measurement of the feed water are dispensed with it may be fed to the boilers direct from the hot well as when the engines are running at sea; thus not only feeding the boilers with hot water in place of cold, but dispensing also with all the extra pumps and pipes necessary when the tanks are used. It will, however, be always better to use also these tanks for measuring feed water in any case, as a comparison of the measurements will give more accurate results.

Taken in conjunction with the measurement of the feed water, the measurement of the condensing water will show with tolerable accuracy the amount of steam used and the amount of leakage and condensation.

Taken separately the measurement of the condensing water is to be preferred to the measurement of the feed water, because while either gives an accurate measurement of the steam used if there is no priming or leakage; the measurement of the condensing water gives the more nearly accurate result if there is.

Suppose for example, a case in which the boiler primed 20 per cent. of the water used; then while the engine used 80 lbs. of steam it would be charged by the feed water measurement with 100 lbs. Error, $\frac{100 - 80}{100} = 20$ per cent.

If the terminal pressure in the cylinder were 10 lbs. and the temperature of the hot well were 120° the total heat brought into the condenser would be:

Steam,	80 lbs.		
Pressure,	10 "		
Total heat,		1172°·8	
Less Temperature, Hot Well,		120°	
Heat, per lbs.		1052.8	
Total, 80 × 1052.8			84124.
Water, primed,	20 lbs.		
Temperature, on entering,	193·9		
Less Temperature, Hot Well,	120		
Heat extracted, per lbs.	73·9		
Total heat extracted from water = 73·9 × 20			1478
Total heat extracted from water and steam, =			85602.

This is the heat which would appear in the condensing water, and if it were all charged to the steam condensed the computed weight would be:

$$\frac{85602}{1052{\cdot}8} = 81{\cdot}3 \text{ lbs.}$$

The actual amount of steam was 80 lbs. Therefore the error:

$$\frac{81{\cdot}3 - 80}{81{\cdot}3} = 1{\cdot}6 \text{ per cent.}$$

The same reasoning applies to the leakage and condensation.

Knowing from former experiments the available heat in the weight of coal consumed, there are only four channels through which this heat may disappear, viz.:

1. With the gases through the smoke-stack.
2. Radiation from surface of boilers, pipes, etc.
3. By change into work.
4. Overboard with the discharge water.

If the boilers, cylinders, pipes, etc., are well lagged with non-conducting material, the radiation may be neglected, and we have:

$$\text{Efficiency of boiler} = \frac{\text{heat rejected in water} + \text{work,}}{\text{total heat in coal.}}$$

$$\text{Efficiency of engine} = \frac{\text{Work.}}{\text{heat rejected in water} + \text{work.}}$$

The "Tennessee" is a ship recently fitted with new machinery by Messrs. John Roach & Son, of the Morgan Iron Works, New York.

HULL.

Length on load line,	335 ft.
Length over all,	353 ft.
Beam,	45 ft.
Load draft (mean),	20 ft.
Displacement, . . . (tons of 2240 lbs.)	4240
Mid-ship section,	678 sq. ft.
Estimated horse-power for a speed of 14 knots,	2900

MACHINERY.

A set of compound horizontal back-acting engines, there being two cranks at right angles, each crank being connected with one high pressure and one low pressure piston upon the same rod.

Number of high pressure cylinders,	2
Diameter " " "	40″
Number of low pressure cylinders,	2
Diameter " " "	78″
Stroke of all pistons,	40″
Condensing surface, outside of tubes.	8000 sq. ft.

BOILERS.

10 horizontal tubular boilers, 2 furnaces each.

Total grate surface,	478 sq. ft.
Total heating surface,	12,835 "
Total super-heating surface,	1,000 "
Intended steam pressure, by gauge,	65 lbs.

It will appear from a comparison of the experiment with the following figures that the water necessary to condense the steam used by a set of engines sufficiently powerful to drive a ship of 4000 tons displacement through the water at a speed of 14 knots per hour could have been measured by a *single tank* similar to those used.

Indicated horse power,	2,900
Pounds of steam for each horse power, per hour,	20
Total weight of steam used,	58,000 lbs.
Temperature of hot well,	100°
Units of heat to be extracted from each lb. of steam reduced to temperature of hot well from temperature of terminal pressure in low pressure cylinder,	1,055

Total units of heat extracted,	61,190,000
Difference between injection and discharge,	50°
Pounds of injection-water necessary per hour,	1,223,800
Cubic feet of water necessary per hour,	18,958
Capacity of one tank at 72″ head with all holes open,	20,944
Excess of capacity,	9 per cent.

The independent circulating pumps were furnished by Messrs. Geo. F. Blake & Co., of Boston, Mass. They were selected for the "Tennessee" on account of occupying less space than any other pumps offered. The valve motion of the Blake pump has also an advantage over any other pump on the market. Fig. 4 shows a general sectional view of the steam cylinder, valve and valve chest, and Fig. 5 a plan of auxiliary valve seat.

FIG 5.

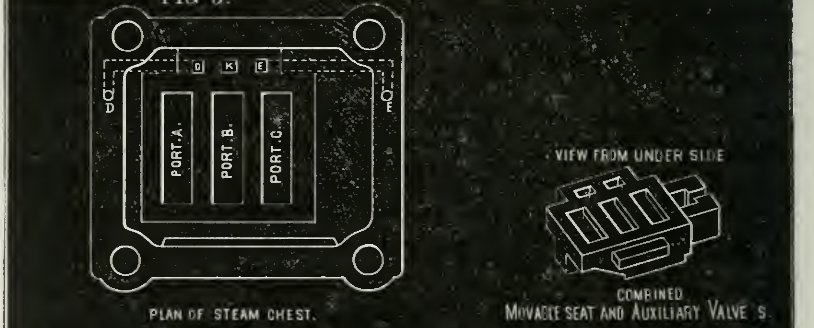
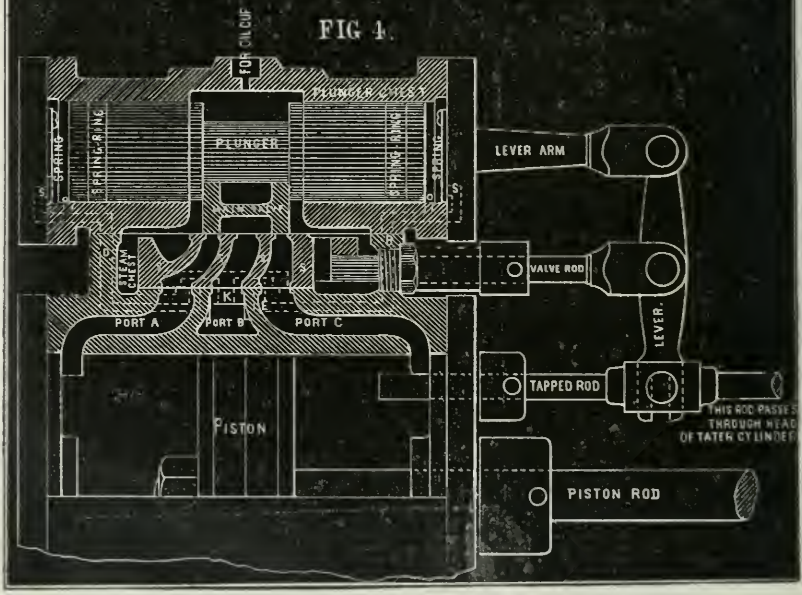


FIG 4.



The tappet rod passes through the heads of both steam and water cylinders, is moved in one direction on being struck by the steam piston just before reaching the end of the stroke, and the reverse when struck by the water piston. This arrangement allows the distance between the pump and the steam cylinder heads to be reduced to only that necessary to draw back the glands for packing. When the valve is moved by any tappet on the piston rod, the distance between the cylinder heads must be at least the length of the glands, plus the length of stroke.

The tappet rod is connected through a vibrating lever and stem to a casting which combines both the auxiliary valve and a movable seat for the main steam valve. The main valve is an ordinary "D" valve sliding upon the movable seat, and held between two shoulders of a supplementary piston or plunger.

The ends of the supplementary piston or plunger are fitted in their respective cylinders, which are cast in one piece with the main valve-chest, the outer ends of these cylinders being connected with openings under the auxiliary valve by little ports cast in the chest. These small ports lead from the auxiliary valve-seat towards each end of the supplementary cylinder, and are divided so as to enter at two different points, one through the head, and the other some distance from it, this last being covered by a piece of sheet brass acting as a valve which allows steam to enter the cylinder but opposes its exit.

In order to understand the action of the valve, consider the case when the piston is moving to the right. The movable seat or auxiliary valve having been previously moved to the left, the former partly closing the ports in the valve seat, the plunger and main valve will have been moved to the right, thus admitting steam to the left of the piston, and releasing it from the right. The piston moving steadily toward the right will, when near the end of its stroke, strike the tappet rod, moving it, and with it the auxiliary valve first into position shown in Fig. 4. The ports to either end of the supplementary cylinders are closed, but the main steam port to the left and the exhaust port to the right end of the main cylinder are yet open, the main valve being still at the extreme right. The main piston being still exposed to the steam pressure continues on towards the right, and moves the auxiliary valve with it until the steam communication is opened by the small ports to the right end of the supplementary cylinder, and at the same time the steam in the other end is released.

The full pressure of steam then acts on the plunger or supplementary piston to move the main valve to the left and admits steam to the right hand end of the steam cylinder. At this instant the main piston is within a fraction of the end of its stroke, but may continue to move toward the end until the steam has had time to overcome the inertia of the plunger. When this has been overcome it moves rapidly to the left until the left end of the plunger has closed the branch port of the cylinder, and the other branch in the head being already closed by the brass valve the steam remaining in the cylinder cannot escape, and the supplementary piston is gradually brought to rest by the accumulating press between the piston and the head. During this interval the main piston commences its return stroke. So far the action is similar to the ordinary auxiliary valve motion.

In all steam pumps which have only this motion it will happen that when the pump is running very rapidly, as when it sucks air, that the piston will move past the point where the auxiliary valve admits steam to the plunger, and will strike the head before the steam has time to act upon the valve. But in this pump if the main piston continues towards the head it must draw with it the movable seat, until the right hand port passes the outer edge of the main valve, opening the port to steam, and the left hand port passes the inner edge opening the left end of the cylinder to exhaust. Under the above circumstances, the main piston will make a return.stroke even though the supplementary piston and main valve should not have time to move at all.

(To be continued.)

Improved Chromolithographic Process.—Messrs. Johnson, of Hatton Garden, London, have invented a new and very economical process for producing chromolithographs. In place of using a special stone for each color, necessitating as many separate impressions as there are colors, the entire subject is drawn upon a single stone and a proof is taken on a thin sheet of copper. This sheet is then cut out carefully according to the desired contour of the colors, and upon each of the portions is fixed a solid block of color previously prepared. The whole is combined into one form, and is printed on an ordinary lithographic press, all the colors at once.

EFFICIENCY OF FURNACES BURNING WET FUEL.

AS DETERMINED BY EXPERIMENTS ON A LARGE SCALE.

By Professor R. H. Thurston, A. M., C. E.

A Paper read before the American Society of Civil Engineers, October 21st, 1874.

1. The writer was recently called upon in the course of professional practice, to determine the relative economical value of two forms of furnaces which were in use for burning wet fuel.

The use of fuel, like spent tan or sawdust, actually wet with water or sap, is so unusual, and is so seldom seen by the engineer, that a detailed account of an experimental investigation made upon two distinct varieties of furnace burning spent tan, wet from the leaches, will probably be considered as important and interesting, by the other members of the Society, as it was by the writer.

2. Formerly, it was thought impossible to burn this waste product of tanners, and it was either thrown away, at considerable expense for carting, or was mixed with dry wood or other good fuel at some cost, or it was dried in the open air by the sun, or by artificial heat in kilns. Within a few years, it has been found that with exceptional skill on the part of the fireman or "stoker," it could be burned with some success in furnaces only differing from those of ordinary construction by having a brick arch turned above the grates, in others having "cone" grates with special arrangement and proportions of air space, and with excellent results in a furnace having an overhead brick arch, with a grate so proportioned that a considerable amount of fuel could fall into the ash-pit and burn there, and with the separate "ovens," two or more in number, so arranged that the products of active combustion in one furnace should be mingled *en route* to the boilers, with the products of distillation and with moisture expelled from the fuel, in a similar adjacent "oven," or furnace, which fuel was, at the same time, drying under the heat radiated from the furnace walls and arch, and received from the fire in the ash-pit, thus desiccating preparatory to subsequent combustion. The latter requisite of preliminary desiccation, was secured also by a system of "alternate firing" of the separate feed-holes in the same oven.

3. The secret of success would seem to be—as indicated by the examination of a large number and of a considerable variety of furnaces burning spent wet tan with more or less success—the surrounding of the mass of wet fuel so completely with heated surfaces and burning fuel that it may be rapidly dried, and then so arranging the apparatus that thorough combustion shall be secured, and that the rapidity of combustion be very precisely equal to, and shall never exceed, the rapidity of desiccation. Where this rapidity of combustion is exceeded, the dry portion is consumed completely, leaving an uncovered mass of wet fuel which refuses to take fire, and then combustion ceased entirely.

FIG. 1

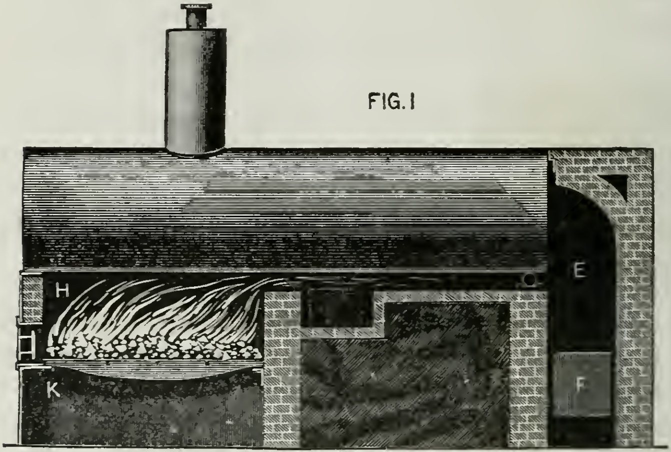
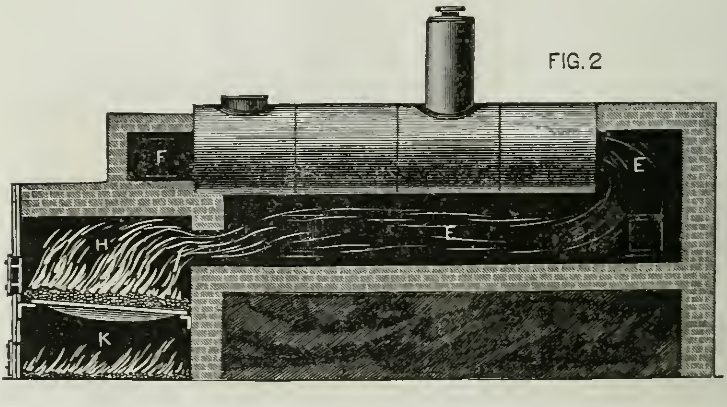


FIG. 2



In the ordinary steam-boiler furnace, Fig. 1, wet fuel has never, so far as the knowledge of the writer extends, been burned with even approximate success. Withdrawing the grates from under the boiler, and securing a reservoir and radiator of heat, by throwing over them a brick arch, as in Fig. 2, gives a form of furnace, known either as a Morrison or a Crocket furnace, in which wet fuel has been burned with partial success, and when the grates are so set that some fuel may fall into the ash-pit as it dries, and there burn, the conditions become those of the second case to be described. The use of the form of grate—shown in Fig. 3 (enlarged in Fig. 4)—giving ample space for fuel falling into the ash-pit, ensures still freer combustion. This peculiar form of section also secures freedom from warping when highly heated.

FIG. 3

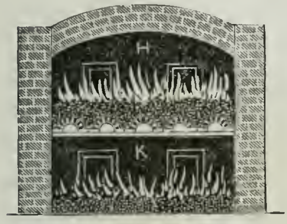
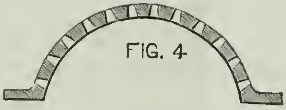


FIG. 4



4. The first example of a furnace burning wet tan, of which the efficiency was determined by the writer, was of the kind known as the "Thompson Furnace," which embodies all of the favorable conditions described in the preceding paragraph. This furnace is shown in section, Fig. 5.

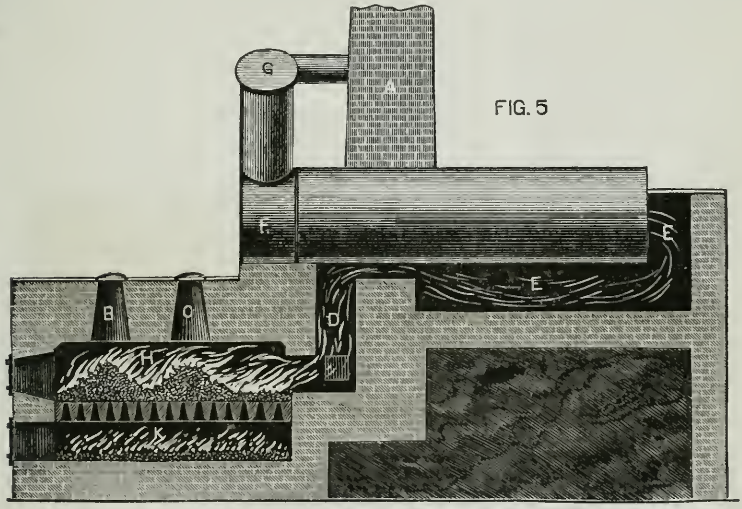


FIG. 5

There were six "ovens" placed side by side, in two sets of three each, the chimney rising between them as shown at A. The grate surface of each oven was 9 feet long, and 4 feet 4 inches wide, giving a total area of 234 square feet. Each furnace was charged through two holes, B and C, in the top of the furnace arch, the proper method being to fill these holes alternately. The grates were of fine brick, spaced about ⅜ inch apart, and supported along the middle line of the ash-pit by a brick wall. The thickness of these grates was nearly 3 inches. They were in four pieces, breadthwise the furnace, a pair on each side the middle wall supported by abutting against each other in a manner somewhat resembling an arch of but two voussoirs. Two doors at the end of each ash-pit permitted cleaning to be readily effected. The gaseous products of combustion leaving the furnaces entered a "mixing chamber" D, common to each set of furnaces, and thence passed through the flues E E to the extreme end of the boilers, returning through the tubes to the smoke-boxes F, and through the iron flue G to the chimney.

5. The steam boilers were three in number, of the plain multitubular variety. Two were four feet in diameter, 14 feet in length, and contained 32 four-inch tubes each; the other was five feet in diameter, 12 feet long, and contained 78 three-inch tubes. The total heating surface, reckoning all of the tube surface, one-half the surface of the shell and all of exposed surface of the tube plates, was approximately 2000 square feet. Of this a portion was ineffective, the lower tubes being choked with ashes, and the remainder was partly covered with deposit. The chimney was 90 feet high.

6. The feed-water was heated by the exhaust steam of the engine driving the machinery of the tannery, very nearly, if not quite to the boiling point, in a closed heater. The exhaust steam mingled directly with the water. On reaching the tank in which the water was measured the feed water had cooled down to 205° Fahr.; thence it passed through the pump, and a considerable length of pipe across the street separating the engine from the boiler-house, and finally, around to the back end of the boilers, where branch pipes conducted it to each boiler.

The temperature of the feed when entering boilers could not, of course, be determined, but it was probably at least as low as 190° Fahr., which is the temperature assumed in the estimate of efficiency, and it may have been somewhat lower.

7. The measurement of the fuel was made as it lay on the leach, before it was disturbed for the purpose of being removed to the boiler-

house, this precaution being taken to avoid error arising from possible changes of volumes due to such disturbance. In one case this transportation to the furnace was performed by a screw, as grain is sometimes moved, and in the other case by cars, capable of carrying nearly a cord, into which the leach was thrown from the leach by hand, and then was dumped at the furnace doors. A careful measurement showed the full leach to contain 8·04 cords of tan. From this 0·34 cord was taken to be weighed after being compressed until it was, as nearly as could be judged, as compact as when in the leach.

8. Commencing at 9 o'clock A. M., the trial continued until the remaining 7·7 cords were burned, closing at 10 o'clock P. M.

9. The feed-water was measured by cutting the feed-pipe between the heater and the feed-pump, and conducting the water from the former into a wooden box 18 inches wide and four feet long. The pump drew the water from this box, which ordinarily stood full to the top. Occasionally, the water supply from the heater was shut off, and the time which was occupied by the pump in reducing the level of the water one foot was noted. This was invariably very precisely 4 minutes. The quantity of water pumped into the boiler from the beginning to the end of the trial was 5625 pounds, or 90 cubic feet per hour.

10. The capacity of the pump was originally barely equal to the requirements of the case, and, at this time, its valves leaked somewhat, making it necessary, not only to run the pump at its full speed throughout the trial, but to keep the fires considerably below their maximum intensity to avoid the necessity of putting on the steam auxiliary to prevent the water getting dangerously low. The maximum evaporation on the trial was thus determined by the capacity of the pump. The flue dampers were kept, as an average, something more than half open. The engineer estimated that he could have burned the fuel with nearly fifty per cent. greater speed, obtaining a proportionably increased evaporation, could the pump have supplied so much water.

11. The spent tan, coming directly from the leach, was so wet as to part with its water when squeezed, wetting the hand. It had been simply drained a few hours, and was as wet as it could be without dripping. The per centage of moisture is given below.

12. As the result of the trial was considered a matter of great importance, both directly and indirectly, it was essential, not only to

determine the amount of water entering the boilers, but to determine as accurately as possible the quality of the steam made, thus ascertaining how much water left the boilers as steam, and how much was "primed" over from them unevaporated. As, under the conditions of this trial, each pound of steam obtained from the fuel about eight times as much heat as was taken up by water "primed" out of the boiler, the serious error which might arise by crediting the fuel with the evaporation of all the water entering the boiler, in cases where even a moderate amount of priming occurred, is evident. Instances sometimes occur in which more water passes off unevaporated than is actually turned into steam. At least one instance has occurred in the experience of the writer in which the average amount of water primed exceeded by more than one hundred per cent. the weight of steam made, the percentage of priming as the expression is used in this paper, being over sixty per cent. The error arising from the neglect of this circumstance told nearly proportionally in favor of a really very poor boiler. A good boiler ought not to "prime," when working properly, over ten per cent. when unprovided with superheaters. Five per cent. priming would represent good work, and as low as three per cent. has been attained.

13. The first precise determination of the amount of priming in steam boilers was probably made by the writer in November, 1871, at a competitive trial of five steam boilers entered at the Exhibition of the American Institute, the trial being made at the request of a Committee of Judges of which he was then Chairman.*

In that instance, a large surface condenser of about 1100 square feet area of condensing surface was used, in which all of the steam made by the boiler on the trial was completely condensed. The water fed into the boiler was measured by a meter, and, on issuing from the condenser, was again caught in a tank. The condensing water, which amounted to some ten tons per hour, was measured by a meter.

The temperature of the injection and discharged water, of the feed, the steam, the water of condensation, and of the escaping products of combustion, were carefully ascertained by suitably arranged thermometers and pyrometers, and were recorded in a log kept by selected students of the Stevens Institute of Technology. The fuel and the ashes were weighed, and all data were obtained and recorded with the greatest possible care.

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* Trans. American Institute 1871–2; Journal Franklin Institute 1872; Van Nostrand's Engineering Magazine, 1871.

RESULTS OF THE COMPETITIVE TRIAL OF STEAM BOILERS AT THE FAIR OF THE AMERICAN INSTITUTE, NOVEMBER, 1871.

NAME.	SQUARE FEET.		Ratio of Heating surface to Grate surface.	TOTAL WEIGHTS.					Ratio of water primed to water evaporated.	MEAN TEMPERATURES.						
	Grate surface.	Heating surface.		Coal.	Combustible.	Feed.	Steam.	Primed water		Injection.	Feed.	Water of condensation.	Discharge.	Steam.	Superheat.	Flues.
	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	O.	P.
Root	27	876½	32·5	3,800	3,185·5	27,896	27,896	0·	0·	45°·94	45°·94	58°·31	143°·1	334°·6	16°·08	416°·6
Allen	32¼	920	28·5	5,375	4,527	39,670	39,670	0·	0·	45°·5	45°·5	63°·48	154°·76	330°·63	13°·23	345°·87
Phleger	23	600	26·1	2,800	2,274	20,428	19,782·94	645·06	3·26	45°·65	45°·65	54°·38	120°·83	321°·06	0°·	503°·76
Lowe	37¾	913	24·2	4,400	3,705	34,000	31,663·35	2,336·65	6·9	45°·0	45°·0	54°·8	131°·5	319°·48	0°·	389°·6
Blanchard	8½	440	51·8	1,232	1,047·5	10,152·5	9,855·6	296·9	3·	44°·4	44°·4	49°·49	106°·14	323°·75	0°·	221°·67

RESULTS, ETC.—(Continued.)

NAME.	Total British thermal units.	Total units per pound of combustible.	APPARENT EVAPORATION.				ACTUAL EVAPORATION.		Equivalent evaporation of water at 212° Fahr. and atmospheric pressure.	Square feet of heating surface required to evaporate one cubic foot of water per hour.	Coal, lbs. per square foot, grate surface per hour.	Efficiency: actual evaporation of fuel divided by theoretical.
			Per pound of coal.	Per pound of combustible.	Per square foot of grate surface per hour.	Per square foot of heating surface per hour.	Per pound of coal.	Per pound of combustible.				
	Q.	R.	S.	T.	U.	V.	W.	X.	Y.	Z.	Z 1.	Z 2.
Root	32,751,834·34	10,281·53	7·34	8.76	86·09	2·65	7·34	8·76	10·64	23·59	11·73	0·709
Allen	46,387,827·1	10.246·92	7·38	8.76	102·51	3·59	7·38	8·76	10·60	17·41	13·88	0 707
Phleger	23,066,685·39	10,143·66	7·26	8.95	73·70	2:83	7·07	8·70	10·49	22·74	10·13	0·699
Lowe	37,228,739·072	10,048·24	7·68	9.22	75·06	3·10	7·20	8·55	10·40	21·63	9·71	0·693
Blanchard	11,485,777·35	10,964·94	8·24	9.69	99·53	1·92	8·00	9·41	11·34	33·48	12·10	0·756

14. The tabular statement of the results, as given in the report of the Committee, is reproduced as they are not otherwise obtainable by engineers generally, and as they are interesting and valuable in themselves, and particularly, as affording a useful standard with which to compare the results obtained during this trial of tan-burning furnaces. The method of determining the percentage of priming will be given below. It should be stated that the Root and the Allen steam boilers were of the "safety" or "sectional" class; the Phleger boiler was also composed of small tubes, but was surmounted by a large drum which was intended to contain some water, thus differing essentially from the two preceding in construction, and in the fact that no portion of the heating surface was above the water-line. The Root and Allen boilers both had a considerable amount of superheating surface. The Lowe and the Blanchard were peculiar forms of multitubular boiler, the former being distinguished by having a peculiarly designed combustion chamber, and the latter by its unusually large proportion of heating surface, as compared with the area of grate, and by its dependence upon a forced draught. All of these boilers gave exceedingly creditable results at this test.

(To be continued.)

TEST TRIAL OF THE LYNN PUMPING ENGINE.

SECOND REPORT OF THE BOARD OF ENGINEERS, TO THE PUBLIC WATER BOARD OF LYNN, MASS.*

Gentlemen:—The object in presenting our First Report, of December 13, 1873, immediately after the conclusion of the test trial, was to enable your Board to make a settlement with the contractor for the engine. It was of primary importance, therefore, to give the results of the experiments, the capacity and duty of the pumping engine, requirements of the contract, rather than any description of the engine, or the manner of conducting the test; but it seemed that

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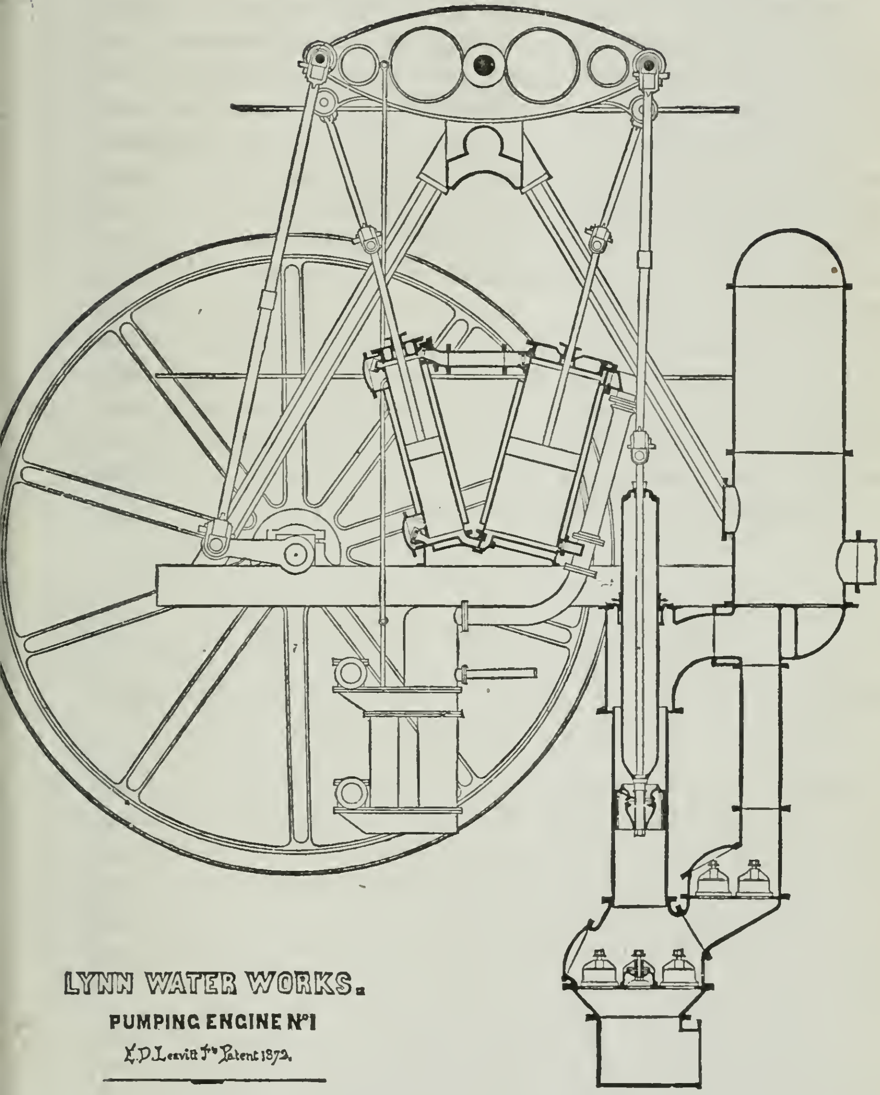
*[A preliminary note upon the character and performance of this Lynn pumping engine appeared in this Journal for January, 1874. The final report of the Board of Engineering Experts appointed to test this engine, appeared six months later. The novel construction of the engine and the exceptionally good performance of it at the time these tests were made, make it desirable in our opinion, to lay before our readers the essential portions of this Final Report, together with the First and partial Report as an appendix.—Ed.]



LYNN WATER WORKS.

PUMPING ENGINE No. 1

E. D. Leavitt Jr. Patent 1872.

something more than this brief report was due to ourselves and the engineering profession, and that a full record should be published, descriptive of the design and arrangement of the engine, the manner of conducting the experiments, and the data obtained, to enable any one conversant with such matters, not only to criticise our modes of test, and our conclusions, as given in the former report, but also to afford valuable information for future constructions and investigations. Subsequent revision of our data has not led us to change our previous conclusions, and what we propose now is to give what may be considered a narrative of the trial, a preservable copy, for our own use, and that of the profession especially, of our records and observations, with descriptions and drawings of the engine and its connections.

The pumping machinery, complete, was furnished and erected under a contract with Mr. George H. Norman, of Newport, R. I. The engine, compound cylinders, with beam, crank and fly-wheel, was designed by Mr. E. D. Leavitt, Jr., of Cambridgeport, Mass., and built by Messrs. I. P. Morris & Co., of Philadelphia, Pa. There are many novel features in the machine, which have been patented by the designer, the most noticeable of which, as shown in the cut, is the arrangement of the steam cylinders, which are located under the beam centre and incline outwardly, so that their pistons are connected to the opposite ends of the beam, and move in opposite directions. The top of the high-pressure cylinder exhausts, therefore, into the top of the low-pressure cylinder, and the bottom of the high-pressure cylinder into the bottom of the low-pressure cylinder. By this arrangement the passages between the two cylinders are made very short and direct. A single valve controls the connection between the two cylinders at the bottom, whilst two valves are used in the connection at the top, one close to each cylinder, so that the capacity of this passage is not added to the clearance of the high-pressure cylinder when being filled with steam, nor is it exhausted when the low-pressure cylinder is being exhausted. All the steam valves are gridiron slides. The high-pressure valves have a cam cut-off, controlled by a governor, readily adjustable to variable speeds. All the other valves are worked by positive cams. The cams are all of large radii, so that the opening and closing of the valves are almost instantaneous. Both cylinders are steam-jacketed at sides and ends, and, together with the steam connections, are clothed with asbestos covering and lagged with black walnut.

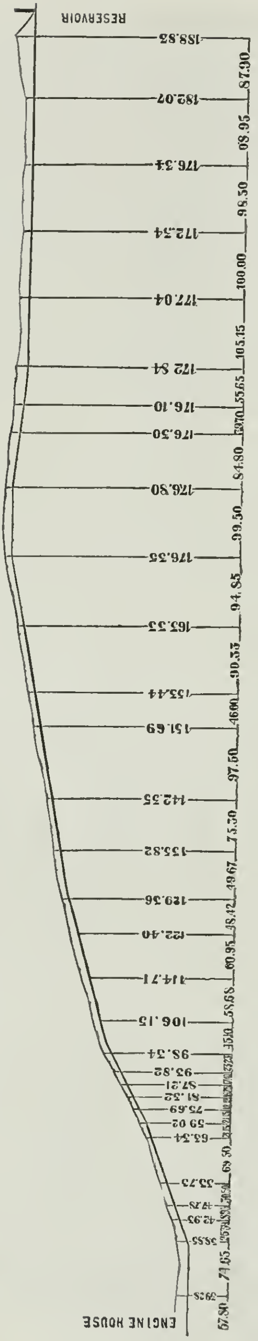
The air-pump is double-acting, and worked by a connection with the beam. The discharge from the hot-well is into the pump-well, and the boiler feed-water is drawn from the hot-well by an independent donkey steam-pump.

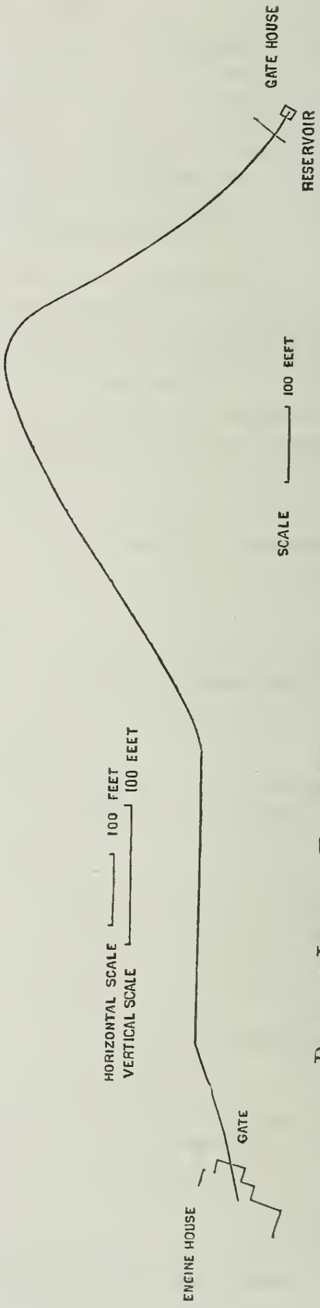
The pump is of the Thames-Ditton variety, bucket and plunger-pump. There is a supplementary pipe and valves to reduce the friction incident to the passage of the water through a single bucket valve in the piston. The valves are of the usual double beat form; the bottom, or foot valves, are seven in number, the upper valves three—one in the piston and two in the supplementary passage; each of the exterior bottom valves has an independent cover on the chamber, for the readier inspection and removal of the valves. To supply air to the air chamber, there is a small air-cock on the lower valve chamber. The air drawn in through this cock on the up-stroke of the pump somewhat reduces the quantity of water discharged by the pump. Careful experiments, previous to and in the early part of the test, established the effect of this cock, by measurements at the weir, and an uniform opening of this cock was kept during forty-eight hours of the trial. During the other four hours the average loss of action was a trifle less than during the forty-eight hours, during one hour the cock being completely closed.

Boilers.—The boilers are two plain horizontal tubulars, set in brick-work, fired beneath, flame passing the length of the boiler and returning through the tubes to a front connection, thence passing up into a single flue on the top of the boilers in brick-work, and to the chimney. There was no clothing at the front end of the boilers. There were automatic dampers attached to the boilers, but during the experiments they were disconnected and worked by hand.

Mains.—The water is drawn by the pump from a large well, supplied by a main from the collecting pond, and discharged through a twenty-inch force main. This main is of cast iron to the point marked gate in the cut, thence by cement-lined sheet-iron pipe of the same diameter, to the bottom of the gate-house in the service reservoir, and thence by a vertical cast iron pipe of sufficient height to discharge into a wooden trunk, connected with a weir box, where the capacity of the pump was determined. No record has been preserved of the exact position; the lines both in the horizontal and plans given in the cut, are from recent surveys, made since the trial, on the surface of the ground, and are probably very nearly approximative. On the main, there are two gates and one check valve.

Profile of Ground over Force Main from Engine House to Reservoir.





Plan of Line of Force Main from Engine House to Reservoir.

TABLE OF DIMENSIONS.

Diameter of high-pressure cylinder	17½	inches.
“ low- “ “	36	“
“ high- “ “ piston rods	3	“
“ low- “ “ piston rods	3¾	“
“ air pump	11¼	“
“ pump-barrel	26 1-10	“
“ plunger	18½	“
“ bottom and supplementary valves outside lower seat	15⅞	“
“ “ “ inside upper “	10	“
“ piston valve, outside lower seat	22	“
“ “ “ inside upper “	16½	“
“ of fly-wheel	26½	feet.
Length of stroke of steam and water pistons	7	“
“ “ air-pump	49½	inches.
Distance between end centres of beam	14	feet.
Steam lead, high-pressure cylinder, top	0	
“ “ “ “ bottom	0	
“ “ low- “ “ top	0	
“ “ “ “ bottom	1-16	inch.
Exhaust lead, high-pressure “ top	1-16	“
“ “ “ bottom	1-16	“
“ low- “ “ top	5 3-16	inches.
“ “ bottom	3	“
Closure before end of stroke :		
High-pressure cylinder, top	9⅞	“
“ “ bottom	14 11-16	“
Low-pressure “ top	6	“
“ “ bottom	5 5-16	“
Clearances :		
High-pressure cylinder, top	.0231	of vol. of cylinder.
“ “ bottom	.0360	“ “
Low- “ “ top	.0109	“ “
“ “ bottom	.0104	“ “
Top connection between cylinders	.0834	of high-press. “
Weight of fly-wheel	24,000	pounds.
“ beams	9,500	“
“ moving parts connected with beam	11,000	“
Boilers :		
Diameter of shell	5	feet.
“ drum	3	“
“ tubes	3	inches.
Length of shell	16	feet.
Height of drum	6	“
Length of grate	5	“
Width of grate	5 feet 6	inches.
Force Main :		
Length of force main from pump to top of vertical pipe at reservoir,	1,904	feet.
Height of top of vertical pipe above bottom of well	163·34	“

RECORDS OF THE TRIAL.

During the continuance of the test, one of the subscribing engineers was always on duty at the engine-house, often two, and sometimes four. The measures of the weir were taken by two members of the board, and the heights of the water over the weir were checked by them. Gauges and scale were carefully tested, and every provision was made to secure accuracy of observation and record. Mr. Hoadley, of our board, was, during the whole trial, on committee business at the State House, but had previously arranged with us the mode of conducting the experiment; had made a preliminary test with us, and was represented during this by his assistant, Mr. Huntoon.

Two watches of assistants were detailed, one for the engine-room, the other for the boiler-room, but were relieved in portion of their duties, from time to time, by the experts. Other assistants were employed in recording the heights of the water over the weir, and in dividing and measuring the indicator cards as taken from the steam cylinders and pump.

The duties of the assistants in the engine room, were to take indicator cards from each end of both cylinders hourly, to make observations, and records as follows:

RECORDS OF THE ENGINE ROOM.

Date.	Time.	Counter.	PRESSURES.				TEMPERATURES—DEG. FAHRENHEIT.					Depth of water in well.	FEED WATER.		
			Steam, lbs.	Vacuum, inches.	Water. lbs.	Barom., inches.	Steam.	Hot well.	Pump well.	Feed water.	Outside air.	ft.in	Cask No. 1. C'ks.	Cask No. 2. lbs.	Total lbs.
December 10...	11 a. m.	242,646	75½	27¾	63	30·14	325	98	40	91	37	8·1¼	3	850	200
December 12...	3 p. m.	300,003	75¾	28	63½	29·68	324	91½	41	96	38	8·1	373	310	130,240

The indicators were Richards' patent and Elliott & Co.'s make. They were carefully tested before the trial; and at about the middle of the trial the indicators on each cylinder were changed from one end to the other of the cylinder, so that half of the cards at the top and half at the bottom were taken by different indicators. The springs used in the high-pressure cylinder indicators were 32 lbs. to the inch; in the low, 16 lbs. to the inch. All the hourly cards taken from 9 A. M., December 10, to 3 P. M., December 12, have been divided, measured, and re-measured, and will be found tabulated toward the end of this report.

It has not been considered necessary to publish the records of the engine room in full. The hourly readings of the counter, and the total quantity of water fed to the boiler will be thus given. Of the records of the other columns, the extreme readings and averages have been deemed sufficient.

The steam, vacuum and water gauges were attached to the engine frame, and connected as directly as possible with the steam-pipe, condenser and air chamber. At the conclusion of the trial, the steam gauge was tested and its reading was found to be 5 lbs. in excess, at the average of 75½ lbs., and should, therefore, be 70½ lbs. The vacuum gauge was not tested. As the estimate of duty was dependent on the reading of the water gauge this was carefully tested before and after the trial. Its reading at the average of 63·60 lbs. was found to be too small by 0·6 lbs., and should be therefore 64·20 lbs.

The barometer was an Aneroid, placed in the engine room. The records during the trial compare very nearly with the observations of the Signal Service Station at Boston. From the readings of the barometer, the zero on the indicator cards has been established, to which all pressures are referred instead of to the atmospheric line.

The temperature of the steam was taken by a Siefert thermometer, inserted into the main steam-pipe just outside the engine stop-valve.

The temperatures of the hot well were taken at its overflow into the pump-well after a passage of say 25 feet; the temperatures of the pump-well from a thermometer suspended therein; of the feed-water from the lower measuring cask; of the outside air from the front of the engine-house. The thermometers used for all the above observations were of Huddleston's make.

The depth of water in pump-well was taken from a scale in the engine-room, connected with a float in the well. The average reading was compared by ourselves with a bench mark on the wall, which had been referred to the top of the vertical pipe in the reservoir by one of Mr. Davis' assistants.

Feed-Water.—The quantity of water fed into the boilers was determined by an arrangement of casks of measured capacity. An upper cask (No. 1), which could be filled directly from the hot well and discharged into the lower cask (No. 2), which last was connected with a Blake donkey-pump, and was discharged into the boilers. Into cask No. 1, 350 lbs. of water, at 100° Fahrenheit, was weighed and discharged, and at the level of the surface of the water an overflow was cut, so that the capacity of this cask was established at 350 lbs. of water. Outside of cask No. 2, a glass boiler-gauge was placed, connected with the bottom and top of the cask; and beside this gauge was a scale marked accurately to every 100 lbs. of water at 100° Fahrenheit, as it was weighed consecutively and poured into the cask. The working of this arrangement of casks is as follows: An assistant, exclusively in charge, closes the connection between the casks; fills No. 1 from the hot well, closes the connection between the hot well and opens that between the casks, and so continues filling into No. 1 and emptying into No. 2 as fast as drawn out by the feed pump, holding always some balance in the lower cask, and keeping tally of the total number of upper casks filled and emptied. At each hour the engine-room assistant receives the tally of cask No. 1, and notes by the scale on the glass gauge the quantity remaining in cask No 2. From the tally he knows how much water has been drawn from the hot well, and from his observation how much of this water still remains to be fed into the boilers.

Thus, at 11 A. M., December 10, three casks No. 1 had been filled and discharged into cask No. 2, and 850 lbs. still remained in the latter.

$3\times350-850=200$ lbs. fed into the boilers.

At 3 P. M., December 12, 373 casks No. 1 had been filled and discharged into No. 2, and 310 lbs. remained in the latter.

$373\times350-310=130{,}240$ lbs. fed into the boiler.

$130{,}240-200=130{,}040$ lbs. fed into the boilers between the hours of 11 A. M., December 10, and 3 P. M., December 12.

RECORDS OF THE BOILER-ROOM.

The coal used was egg and broken Lackawanna, of good average quality, as found in one of the Lynn coal yards. As no allowance was to be made for cinder or unconsumed coal, and as it was consistent with the method at the late trial of the pumping engine at Lowell, the contractor was permitted to cull or pick the coal, that as little incombustible material as possible might be charged to the boilers. Between the hours of 9.20 A. M. and 11.40 A. M., December 12, 149 lbs. were selected by the contractor from the screenings and fed into the grates. At the close of the trial there were 474 lbs. of cinders, 336 lbs. screened coal, and 355 lbs. of very fine coal from the grates. No account of any of the above quantities have been taken in our estimates of duty or evaporation. The facts are only noted for comparison with other experiments in which evaporation has been predicated on combustible material.

The engine had been started on the afternoon of December 9 and run till 1.30 A. M., December 10. It was started again at 8.50 A. M., and some observations were taken at 9 and 10 A. M., but it was not till 11 A. M. that the trial commenced. At that time the fires beneath the boilers were in good working condition. The water in the boilers was at an established height, and the engine was making the number of revolutions which were found by the weir to give a discharge a little in excess of the capacity contracted for. These conditions were kept as nearly uniform as possible during the whole time of the trial, and when at 3 P. M., December 12, the test trial closed, the engine was still running at the same speed, and the fires continued to be kept in the same working conditions, whilst we made experiments on the quantity of water condensed in the steam jackets.

Two assistants, on alternate watches of about twelve hours each, had charge of the boiler-room observations, and had constant supervision, except when relieved by ourselves or other assistants at meals.

The coal was weighed in lots of 500 lbs. each in a permanent box on the scales, and left there to be drawn from according to the necessities of the fires. As each 500 lbs. was weighed it was set down in the column of gross weights.

In a column marked Separate Weights, was set down the balance left in the box after each firing, and the quantity taken from the box was set down under Grate Charges to boiler No. 1 or No. 2 where it was fired; but under the column Total Coal, was set down the amount of coal used in both boilers; thus, at 9.20 A. M., December 11, 500 lbs. were weighed and 10,500 had been previously weighed and fired. At 9.35 A. M., coal was fired on No. 2 grate, and 460 lbs. were left in the box. 500—460=40 lbs. was charged to No. 2, and the total was increased to 10,540. At 9.45 A. M., coal was fired on No. 1 grate, leaving 310 lbs. in the box. 460—310=150 lbs. was charged to No. 1, and the total was increased to 10,690 lbs. These quantities of coal and times of firing have been plotted on cross section papers, the ordinate divisions representing a scale of lbs. and the abscissa divisions one of hours. From an inspection of the profile thus constructed, the character of the firing may be readily understood. The absolute total fired at each hour may be interpolated, or the relative total properly chargeable at the time, reference being had to the character of firing as shown previous to and after; whether it was light or heavy beyond an average grade line, that is, whether the fireman had been depreciating the character of the fire or improving it. The firing record was commenced before 11 A. M., December 10, and there was no coal fired between 2.45 and 3 P. M., December 12; and the quantities fired at 11 A. M. and 3 P. M. have been established from the grade line on the profile. With these exceptions, the total coal fired at each hour and hereafter given are the quantities interpolated by proportion between the two firings nearest the hour.

The pressures on the gauges of each boiler were observed and noted hourly. On comparison of these gauges with the standard, the reading of gauge, boiler No. 1, was found to be, excess, 2·5 lbs., and of boiler No. 2, 3 lbs. At the average reading, thus, No. 1 reading 76 lbs., should be 73·5 lbs., and No. 2, reading 77 lbs., should be 74 lbs.

Scales graduated to inches were placed against the glass water-gauges of each boiler, the zero being assumed at the height of one foot above the centres of the boilers, and the levels of the water in each boiler above or below the zero were noticed hourly.

The temperature of the feed water was taken from a Siefert thermometer inserted into the feed connection between the donkey-pump and the boiler.

A plugged pipe, filled with oil, was suspended in the main flue, at the top of the boilers, and the temperature of the flue was taken by inserting a Siefert thermometer into the oil.

It will be observed under column Remarks, " 9:20 to 10:30, used steam from main boiler for feed." The engine has no pump connected directly with it, as at Lowell, and it has been usual to drive the donkey-pump directly from the boilers, but for the purposes of this trial it was thought best to drive the donkey by an independent boiler. Unfortunately, at times during the trial, the steam got too low in this boiler, and steam had to be drawn from the main boilers. Each time this occurred was noted, and the aggregate was found to be 8 hours out of the 52 of the trial. By experiments of Messrs. Copeland & Worthen, on the trial of Ridgewood Engine No. 3, December, 1869, it was found that one per cent. of the steam raised for the driving of the engine was used by the donkey. Adopting this basis for the 8 hours, it will be found that during this time as much steam would have been used by the donkey as would have been for the driving of a pump 52 hours, connected as at Lowell with the engine.

(To be continued.)

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THE PRINCIPLES OF SHOP MANIPULATON FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

[Continued from Vol. lxviii, page 330.]

Slotting Machines.

Slotting machines with a vertical cutting movement differ from planing machines in several principles to which the attention of the apprentice is directed.

First,—The tools are in most work held rigidly, in every direction, and not swerving from a pivot as in planing. This is necessary for two reasons; because the force of gravity can not be used to keep the tools in position and because the thrust or strain of the cutting falls parallel to the shank of the tools, and not transversely as in planing machines.

Second,—The cutting movement is performed by the tools and not by the material as in planing.

Third,—The cutting strain is at right angles to the face of the table, acting in the same direction as the force of gravity, and not parallel to the face of the table and the force of gravity as in planing.

The nature of the operation in slotting, and because of the rigid tools, the feed motion has to operate differently from that of a planing machine. The cross-feed of a planing machine may act during the return stroke but not so in slotting machines, the feed movement must take place at the end of the up-stroke after the tool is clearof the material, and as so much of the stroke as is made during the feeding action is lost it leads to the use of mechanism to operate the feed that has a quick abrupt action so as to save extra movement in the cutter bar.

This very interesting principle is overlooked and still oftener not understood among machinists, and will not fail to furnish an interesting example to be investigated, especially the action of the mechanism that operates the feed and the relations this movement bears to the cutter bar motion.

SHAPING MACHINES.

Shaping machines occupy a half-way place between planing and slotting machines, the movements corresponding more to that of slotting machines and the operations of the tools corresponding more to planing machines.

The advantage of shaping machines over planing machines for certain kinds of work is owing to the greater facilities afforded for presenting and holding small pieces or pieces of irregular shape, the supports or tables usually having both vertical and horizontal faces to which the work can be bolted; also in the accessibility and greater convenience of the mechanism for adjusting and feeding the tools.

Shaping machines are provided with adjustable vices, devices for planing circular forms, and other details that cannot be so conveniently used on planing machines. Another advantage of great importance in shaping machines is the positive range of the cutting stroke produced by crank motion, which stops the tool accurately at any point and permits planing of slots and key ways that can hardly be performed upon the common planing machine.

Shaping machines in common use are divided into two classes, one modification that has the lateral feed given to the tools, technically called traveling head machines, and the other with a feed motion of the table carrying the work, called table-feeding machines.

The first modification is better adapted to long pieces that are planed transversely such as cutting toothed racks, and the second to a shorter class of work where the hand adjustments are more frequent.

The most interesting study in connection with modern shaping machines are the principles of the cutting movements produced by the various devices, generally called quick return movements. These devices consist generally of modifications of the slotted lever or variable fulcrum principle, and what is known as 'Whitworth's' quick return motion.

As the intricacy of the subject renders it a difficult one to deal with except by the aid of diagrams, and as the mechanism can be seen in almost any machine fitting shop, I will merely call the attention of the learner to the movements and recommend them as one of the best subjects that can be chosen for diagram demonstration.

These quick return motions are a subject that will not wear out too soon, neither in interest nor in the amount of research that it admits of, and certainly is more useful than many of the nonsensical problems that often take up time uselessly and have no application in practical mechanics.

The remarks relating to turning tools given in a former place apply to tools for planing as well, except that greater stiffness is required in planing tools, both of the edges and the shanks.

BORING AND DRILLING.

Boring, as distinguished from drilling, consists in turning out annular holes to true dimensions, while the term drilling is applied to perforating or sinking holes in the solid metal.

There is also a wide difference in the nature of the two operations that makes a greater distinction still. In boring, the action of the tool is guided by axial supports independent of the hole, while in drilling, the cutting edges are guided and supported mainly from their contact with, and bearing in, the material that is being drilled.

Owing to this difference in the manner of guiding and supporting the cutting edges, and the advantages of axial support for the cutting tools in boring, this operation is one of truth, by which the most accurate dimensions are attainable, while drilling is a comparatively imperfect operation, yet the ordinary conditions of machine fitting are such that nearly all small holes can be drilled with sufficient accuracy and at a much less cost than they could be bored.

Boring may be called internal turning, differing from turning in the cutting movement of the tool and in the cut being made on concave instead of convex surfaces; otherwise there is a close analogy to turning. Boring operations are to a large extent performed on lathes, either with boring bars or by what is termed chuck boring when the material is revolved and the tools are stationary.

Boring operations in the shop may be divided into three kinds: Chuck boring on lathes; Bar boring, when a boring bar runs on points or centres and is supported at the ends only; and Bar boring when the boring bar is supported in and fed through annular bearings.

The principles are different in each of these three plans of boring, and each are applicable to certain classes of work, and in certain cases one plan is right and another wrong.

A workman who can distinguish between these plans of boring and can always determine from the nature of the work which it is proper to adopt, has acquired no small knowledge of machine fitting.

Chuck boring is the usual plan adopted in three kinds of cases. For holes of shallow depth, taper holes, and holes that are screw-threaded.

As the work is overhung in lathe boring there is not sufficient rigidity neither in the lathe spindle nor in the tools to admit of deep boring.

The tools being guided in a straight line and at any angle to the axis of rotation, the facilities for making tapered holes are complete, and as the tools are still, and can be instantly adjusted, this kind of boring is adapted to cutting internal threads, the operation corresponding to cutting external threads, except that the cross motions of the tool block are reversed—that is, the tools are fed to the front towards the operator.

The second plan of boring by means of a bar mounted on points or centres, as they are technically called, is the only plan in ordinary practice of securing true holes; it is, like chuck boring, a lathe operation, and one for which no better machine than a lathe has yet been devised, and it may be added is not required. It is indeed a question whether in ordinary machine fitting there is not a gain by performing all the boring in this manner whenever the rigidity of the boring bar is sufficient without auxiliary supports. Machines for this work could then be used in turning and boring as occasion required, and greater accuracy of the work attained than is possible when the boring bar is supported in annular bearings.

When a tool is guided by its turning on centres, its rotation is perfect. The straightness or parallelism of holes bored in this manner is dependent on the truth of the carriage movement that guides the piece, and this is usually a very perfect movement. This kind of boring is practiced in boring steam cylinders, cylindrical valve seats, and for accurate fitting generally.

The third plan of boring with bars that rest in bearings is more extensively practiced, and has the largest range of adaptation. The distinguishing feature in this plan of boring to which the attention of the apprentice is called is, that the form of the boring bar, and any imperfection in its bearings is communicated to the hole that is bored, and any want of straightness in the bar is also communicated to the hole. This, of course, applies to cases where the bar is fed through fixed bearings placed at one or both ends of the hole. If a boring bar is bent, or out of truth between its bearings, the diameter of the hole is governed by the extreme sweep of the cutters, but as the cutters move along and come nearer to the rest or bearing, the bar then runs true and the hole is tapered. The same rule, in one sense, applies to chuck-boring, the form of the lathe spindle being communicated to the holes bored ; but lathe spindles are presumed to be quite perfect compared to boring bars. Besides it is the form of the spindle that may affect the truth of the hole, while in the case of a boring bar it is the bearings.

The prevailing custom of casting machine frames in one piece or in as few pieces as possible, leads to a great deal of bar boring, nearly all of which is performed accurately enough and much upon this third plan of boring. By setting up temporary bearings to support the bar and improvising means of driving and feeding the boring bars most of the boring can be done without mounting the castings on machines, which would in many cases be impossible.

In but few cases will the learner see the importance of studying principles so clearly demonstrated as in this matter of boring ; even a whole life-time of practical experience seldom leads to a thorough understanding of the matter, and questions asked in regard to different plans of boring will be less intelligibly answered than if relating to any other branch of work.

Drilling as an operation differs in principle from almost every other one in metal cutting. The tools instead of being held and directed by guides or spindles, steady and support themselves from the bearing of the cutting edges.

The common triangular pointed drill as a cutting tool is capable of withstanding a greater amount of strain upon its edges, and rougher use than any other implement used in machine fitting. The rigid support which the edges receive and the tendency to press the edges to the centre of the tool instead of to tear them away as in other cases, allows drills to be used that are imperfectly shaped, imperfectly tempered, and even when the cutting edges or lips are of unequal length.

Nearly all of the difficulties that once attended drilling are now removed by the machine-made drills that are manufactured and sold like files, and used generally throughout America, and everywhere else where they are known. Such drills do away with fitting to sizes, dressing and tempering, drill true holes, are more rigid than common solid shank drills, will drill to any depth without clearing the holes, and are safe from breaking except by the most careless use.

Drilling tools, except these modern machine-made drills, have been described so many times, and so thoroughly that no further notice can be of use.

A drilling machine adapted to the various requirements of a machine fitting establishment consists essentially of a spindle arranged to be driven at various speeds, and with an eased movement for feeding the drills; a firm table set at right angles to the spindle, and arranged with a vertical adjustment to and from the spindle, and compound adjustment in a horizontal plane. This would constitute a standard drilling machine, but the simplicity of the mechanism required to operate drilling tools is such that it has led to endless modifications; such as column drills, radial drills, suspended drills, horizontal drills, bucket drills, multiple drills, and others.

Drilling more than any other operation requires the sense of feeling, and comes farther from the conditions that admit of power feed than other operations. The speed at which a drill may cut without heating or breaking is not only dependent upon the manner in which it is ground and the nature of the material drilled, but may change at any moment as the drilling progresses; so that hand feed is the best for drilling, and with machines that are arranged with power feed for boring there should be some means of permanently disengaging the feed to prevent its use in ordinary drilling.

I am well aware how far this opinion is at variance with practice, especially in England; yet careful observation will prove that power feed in ordinary drilling is a mistake.

MILLING.

Milling relates to metal cutting with serrated rotary cutters, and differs materially from either planing or turning, the movement of the cutting edges can be much faster than with those that act continuously, because the edges are cooled during the intervals between each cut; that is, in a milling tool with twenty teeth, any single tooth or edge acts but one twentieth part of the time, and as the cutting distance or time of cutting is rarely long enough to generate much heat, the speed of such tools may be fifty per cent. greater than with turning, drilling, or planing tools. Another distinction is the perfect and rigid manner of supporting the cutting edges, which are short and blunt, besides being carried on short mandrils that insures rigidity. The result of this rigid support of the tools is seen in the length of the cutting edges that can be employed, which are sometimes four inches or more in length. It is true the amount of material cut away in milling is far short of what the edge movement would indicate when compared to turning or planing tools; yet the displacing capacity of a milling machine exceeds that of either a lathe or a planing machine. Theoretically the cutting capacity or the displacing capacity of any metal or wood cutting machine, is as the length of the edges multiplied into the speed of their cutting movement; a rule that applies very uniformly in wood cutting, and also in metal cutting within certain limits; but the strains that arise in metal cutting are so great that they exceed all means of resisting them either in the material acted upon, or in the means of supporting tools, so that the length of the cutting edges is limited. In turning chilled rolls in Pittsburgh, tools to six inches wide are used, and the effect produced is as the length of edge; but the depth of the cut is slight and the operation is only possible because of the extreme rigidity of the pieces turned, and the tools being supported without movable joints beneath it, as in a common lathe.

A given quantity of soft iron or steel may be cut away at a much less cost by milling than by any other process that would produce the same result, and more accuracy attained.

A milling tool that has twenty edges, should represent as much wearing capacity as a like number of separate tools, and may be said to equal twenty tools that are duplicates; hence, in cutting grooves, notches, or similar work, a milling tool is the equivalent of a large number of duplicate single tools, which cannot be made nor set with the same truth, so that milling secures accuracy and duplication, that is often more important than speed.

As milling operations are cheaper than planing or turning, the question arises, why not mill all surfaces that can be reached, and do all the cutting that is possible in this manner, instead of using single tools? Any one skilled in shop manipulation would at once answer that the cost of milling tools exceeds that of other tools in a degree that would in most cases balance what would be gained in speed; an answer that would be substantially correct, yet one that should not satisfy a learner, but lead to another question: why are milling tools most expensive? Which may be answered as follows:

First. Solid milling tools consist of a number of edges that must retain the same relative position, there being no independent adjustment of these edges they must be combined in one piece, and each edge stand precisely at the same distance from the axis of rotation; this makes a milling tool a piece of finished mechanism, with accuracy in all of its parts, and something very different from a turning or planing tool that may be roughly shaped and ground to an edge, without any care except as to temper and shape of the cutting point.

Second. Solid milling tools consist of a large number of edges, each of which may be said to depend on all the rest; the derangement of one edge disabling all, for as soon as a single edge breaks, the next in order will have a double duty to perform, and when this one breaks, which is sure to follow, the next edge will have a triple work to do, so that the tool as a whole is dependent upon the endurance of each edge or tooth. It is a reversal of the old adage that "union is strength," for in this case union is weakness.

Third. These conditions limit the use of milling tools to a certain class of work, where the material is clean and soft, and when duplicate pieces are to be made. It is evident that where there is danger of injury to the tools by sand, "hard pins," or any foreign substance in the material milling may become an expensive process. Duplication is in most cases the greatest gain effected by milling; if the apprentice will examine the milling tools in use in an engineering establishment, he will find nine-tenths of them directed to duplication, to cutting grooves of uniform width or making pieces that have the same profile, such as wheel cutting, which is nearly all performed by milling tools.

Many of the difficulties of maintaining milling tools are obviated by using detachable cutters that may be replaced when injured and removed for sharpening; but such a construction of the tools is only possible when they are of large size and when but narrow edges are required. Machines constructed with these detachable tools, and with the plane of rotation parallel to the face of the material, are constructed by an engineering firm in Leeds, England; which for many purposes exceed the performances of reciprocating planing machines. The most extensive experiments that have come within the writer's notice are the milling machines used at Crewe, in England, for cutting away the crank slots in locomotive axles, when the work is 'roughed out' at a rate that far exceeds the performance of any machine that employs but a single tool. The cutters are so arranged that the sum of their cutting action is equal to two or more tools acting continuously, as in turning.

In the manufacture of small arms, sewing machines, and like articles, where the material is always of the best, and where the work is mainly a duplication of pieces, milling can be applied with great success, especially on pieces that are made from crucible steel, which are free from hard spots and may be rendered soft by annealing.

Milling machines, as a class, are among those that admit of endless modification in their arrangement, especially in the means of holding and presenting the material. The essential parts of such machines are a rotary spindle to carry the milling tools, and a traversing platen to hold and feed the material, with an adjustment of the tools to and from the face of the platen.

As there could be nothing gained by following out the details of construction in milling machines, and nothing but what will be at once understood by a learner when he is brought in contact with the machines themselves, the matter is left here with this recommendation to the reader: Accustom the mind to refer continually to the proper method of finishing any piece of work that comes under notice, whether it should be planed on a shaping, slotting, or planing machine, or milled; whether holes should be "chuck bored," or bored with a bar; also, the facilities in favor of these several plans; in short, always keep the mind directed to the operations of planing, turning, boring and milling, because no small share of success in machine fitting must depend upon the choice of proper finishing processes.

SCREW CUTTING.

The processes for cutting screw threads and the tools employed especially for this purpose, constitute a separate class among the implements of the fitting shop, and it is considered best to notice them separately.

Screw cutting is divided into two classes, one where the blanks or pieces to be threaded have axial support, and the tools held and guided independently of their bearing at the cutting edges, technically called chasing; the other process, where the blanks have no axial support, but are guided by the dies and cutting tools.

The first of these operations includes all threading processes where the blank runs on centres, as in lathe cutting, whether performed with a single tool or by dies that are carried positively by the slide rest or by milling processes.

The second includes what are termed bolt cutters, in America, and screwing machines, in England, consisting essentially of devices to rotate either the blank or the dies, and means of holding and presenting the blank to the cutting dies.

Chasing produces screws that are true with respect to their axis, and is the common process for threading all screws that are to have a running motion in use, either of the screw itself, or the nut.

Die-cutting produces screws that may not be true with respect to their heads, that may not be perfectly straight, but still are sufficiently accurate for most uses, especially in clamping and joining together the parts of machinery.

Chasing operations being in a sense lathe work, and involving no principles not already noticed, I will confine what is said to die-threading and to bolt-threading machines, which as simple as they may appear to the unskilled, involve, nevertheless, many intricacies that do not appear upon superficial examination.

The apprentice will find the following modifications: Machines with running dies where the rotation is performed by what is called the head in which the dies are mounted. Machines with fixed dies in which motion is given to the rod or blank to be threaded; machines with expanding dies that open and release the screw without running back; and machines with solid dies in which the screws have to be withdrawn by changing the motion of the driving gearing; making four different types that are more or less distinct.

If these various plans of arranging thread-cutting machines was with reference to different kinds of work it might be assumed that all of them were right, but as a rule they are all applied to nearly the same kind of work, and hence it is safe to conclude that there is one arrangement better than the rest or that one is right and the others wrong; a matter that is to be determined by following through the conditions of their use and application.

First. As between a running motion of the dies and of the blank.

If dies are fixed, the clamping mechanism to hold the blank has run with the spindle and the blank, and the machine must be stopped while fastening the blanks to be cut. The clamping jaws are usually as little adapted to rotation as the dies would be, if carried on the spindle and generally afford more chances for obstruction and accident; to rotate the blank it must, when long, pass through the driving spindle, as the machines cannot well be made of sufficient length to receive long rods.

In machines of this last class that revolve the blanks, the dies have to be opened and closed by hand instead of the driving power, which can be employed for the purpose only when the dies are mounted on the running head.

With running dies the blank may be clamped when the machine is in motion, and as the blank is still, except the feed movement, it may, when long, be supported in any temporary manner; the dies can be opened and closed by the driving power also, and no stoppage of the machine is necessary, so that several advantages of considerable importance may be gained by mounting the dies in the running head, a plan that has been generally adopted of late years by the best makers of machine tools.

In respect to the difference between expanding and solid dies, it rests mainly in the time required to run back, and in the additional mechanism required to reverse the motion of the driving spindle when solid dies are used.

Uniformity of size in the screws is insured by solid dies, but they are more liable to derangement and less easy to repair than the expanding or independent dies.

The main difference between solid and expanding dies, aside from the precision required in adjusting the latter, consists in the firmness with which the cutting edges are held. With a solid die, the edges or teeth being all combined in one piece, are firmly held in a fixed position, while with expanding dies their position has to be maintained by mechanical devices that are liable to yield under the great pressure that arises in cutting. The result is, that the precision with which a threading machine with movable dies will act, is dependent upon the strength of the "abutment" behind the dies, which should be a hard surface that is unyielding, and with as much area as possible.

Connected with dies, there are various problems, such as clearance behind the cutting edge; whether an odd or even number of edges are best; how many threads require to be beveled to perform the cutting, and many other matters about which there are no determined rules. The diversity of opinion that will be met with on these points, and in reference to taps, the form of screw threads, and so on, will convince the learner of the intricacies in this apparently simple matter of cutting screw threads with dies.

(To be continued.)

Chemistry, Physics, Technology, etc.

THE JOINT EFFECT OF BATTERY-CELLS, WHEN DIFFERENTLY COMBINED.

By John P. Merrell, U. S. N.

In speaking of batteries, each cell is always considered to have a certain electro-motive force and resistance, which depend for their value on the construction of the cell, and which for similar cells may practically be considered uniform.

In practice, battery cells are differently arranged according to the nature of the circuit in which they are placed: they may be arranged *in series*, in which case the positive pole of one cell is connected to the negative pole of the next, and so on; they may be connected *for conductivity*, in which case all the similar poles are connected together; and they may be arranged as shown in the figure, that is, partly in series and partly for conductivity, the connection shown being two *in series* and four for conductivity.

The strength of the current flowing in any circuit and due to any arrangement of battery, may be computed by means of the following formula:

$$S = \frac{xE}{\frac{Bx^2}{n} + R} \quad . \quad . \quad . \quad . \quad (I)$$

In which S = strength of current.
E = electro-motive force per cell of the battery used.
B = resistance per cell of the battery used.
n = whole number of cells.
x = number of cells connected in series.
$\frac{n}{x}$ = number of cells connected for conductivity.
and R = interpolar or external resistance.

The truth of formula (I) may be shown by Gavarret's well-known formulæ, bearing in mind, at the same time, the principle that the resultant current in any conductor will be the algebraical sum of all the partial currents flowing in that conductor, currents in one direction being considered positive and those in the opposite direction negative.

Gavarret's formulæ apply to cases of branch or derived circuits, in which the current divides between two or more paths; and are,

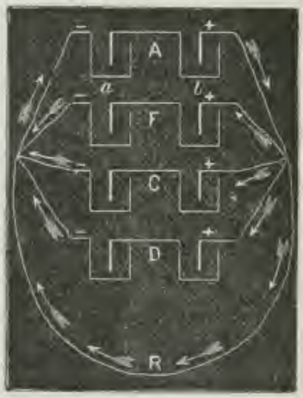
$$T = \frac{abcd}{abc + bcd + cda + dab} \quad . \quad . \quad . \quad . \tag{II}$$

$$S = \frac{E'(abc + bcd + cda + dab)}{L\,(abc + bcd + cda + dab) + abcd} \quad . \tag{III}$$

$$S_A = \frac{E'\,(bcd)}{L(abc + bcd + cda + dab) + abcd} = \frac{E'\,(bcd)}{M} \tag{IV}$$

$$S_B = \frac{E'(acd)}{M}, \ \text{(V)} \quad S_C = \frac{E'(abd)}{M}, \ \text{(VI)} \quad S_D = \frac{E'(abc)}{M}, \ \text{(VII)}$$

In which E' = the total electro-motive force acting in the circuit.
L = the resistance of the simple parts of the circuit.
T = the equivalent resistance of the four branches, whose resistances are respectively a, b, c and d.
S = the strength of current in the simple parts of the circuit; which equals the sum of all the currents in the branches.
and S_A, S_B, S_C, etc., the strength of current in the respective branches, A, B, C, etc.



Now let us consider the condition of things in a circuit similar to the one shown in the figure, letting E and B represent the electro-motive force and resistance of each cell, and R the external resistance. As far as the cell *a* is concerned, all the other cells may be considered simply as so many conductors, each having a resistance B; and the current given by the cell *a* through a circuit so composed would be in the direction of the arrows, the case being one of branch circuits, in which A is the simple part of the circuit, and F, D, C, and R* the branches. Now A, F, C, and D, each having a resistance equal to 2B, we shall have for the current given by the cell *a* in the part A,

$$S_A = \frac{E\,[3R\,(2B)^2 + (2B)^3]}{(2B)\,[3R\,(2B)^2 + (2B)^3] + R\,(2B)^3 = 0} \text{ (from formula III);}$$

in the branch R*, $S_R = \frac{E\,(2B)^3}{0}$ (from formula IV).

and in the branches, F, C and D, $S_F = S_C = S_D = \frac{ER\,(2B)^2}{0}$

Now, considering the cell *b* as the battery, and the cell *a* and all others as simply conductors, the current from *b* would be in the direction of the arrows, and its strength in the different parts of the circuit would be the same as that just determined for the cell *a;* and as these currents are everywhere in the same direction their resultants will be the sum of the two, and we shall have for the strengths of current in the different parts of the circuit due to the combined action of the two cells,

$$S_{A_2} = \frac{(2E)\,[3R(2B)^2 + (2B)^3]}{(2B)\,[3R(2B)^2 + (2B)^3] + R(2B)^3}, \text{ etc.}$$

Let us now take a more general case, that of n cells connected x *in series* and y *for conductivity*, (xy being equal to n), and treat it in the same way. In this case each part of the circuit, except the part R, will have a resistance xB; and we shall have for the current in any row of cells, due to their own action,

$$S = \frac{(xE)\,[\,(y-1)\,R(xB)^{y-2} + (xB)^{y-1}]}{(xB)\,[\,(y-1)\,R(xB)^{y-2} + (xB)^{y-1}] + R(xB)^{y-1}} =$$

$$\frac{(xE)\,[\,(y-1)\,R(xB)^{y-2} + (xB)^{y-1}]}{yR(xB)^{y-1} + (xB)^{y}} \qquad [M]$$

for the current in the part R due to the action of any row,

$$S_{R_I} = \frac{(xE)\,(xB)^{y-1}}{yR(xB)^{y-1} + (xB)^{y}} = \frac{xE}{yR + (xB)} \qquad [N]$$

and for the current in any row due to the action of any other row,

$$S_0 = \frac{(xE)\,(xB)^{y-2}\,R}{yR(xB)^{y-1} + (xB)^{y}} \qquad [O]$$

An inspection of the figure will show that (treating each row as above) where we have *y* rows with *x* cells in each, each row will send into the interpolar wire (R) a current whose strength will be expressed by equation (N), and furthermore that all these partial currents will be in the same direction; therefore, we will have for the resultant current in the wire R the sum of *y* of these partial currents. Or,

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* The part R is taken throughout this discussion as corresponding to *a* in Gavarret's formulæ.

$$S_R = \frac{yxE}{yR + xB} + \frac{xE}{R + \frac{xB}{y}},$$

or, putting $y = \frac{n}{x}$, $$S_R = \frac{xE}{\frac{Bx^2}{n} + R} \quad \text{(q. e. d.)} \qquad [I]$$

A further inspection of the figure will show, that, in each row there is a current in one direction, due to its own action, and whose valu is expressed by equation (M); and (y—1) currents in the opposite direction, due to the action of the other rows, the value of each of which is given in equation (O). This being the case, the resultant current in each row will be expressed as follows:

$$S' = \frac{(xE)\,[\,(y-1)\,R(xB)^{y-2} + (xB)^{y-1}]}{yR(xB)^{y-1} + (xB)^y} - \frac{(y-1)\,(xE)\,R(xB)^{y-2}}{yR(xB)^{y-1} + (xB)^y} =$$
$$\frac{(xB)^{y-1}\,(xE)}{yR(xB)^{y-1} + (xB)^y} = \frac{xE}{yR + xB}$$

It will be noticed that the sum of the resulting currents in the *y* rows equals $\frac{xE}{\frac{Bx^2}{n} + R} = S_R$, which should be the case.

The formula for the case in which the cells are all connected *in series* is readily derived from equation (I). In this case we have but one row and $x = n$, and the formula becomes $S_R = \frac{nE}{nB + R}$.

In the same way when the cells are arranged for *conductivity*, we have n rows, and $x = 1$, and the formula becomes $S_R = \frac{E}{\frac{B}{n} + R}$.

It is easily proved that when, in equation I, $\frac{Bx^2}{n} = R$, we will have the maximum value of S_R. Now, $\frac{Bx^2}{n}$ expresses the equivalent resistance of $\frac{n}{x}$ branches, the resistance of each of which is xB, and as this is precisely the arrangement of the battery we have been considering, we may say that, "The maximum strength of current from a fixed number of cells (n) working against a definite interpolar resistance, (R) is obtained when the battery is so arranged that its resistance shall as nearly equal the interpolar resistance as possible."

EARTH BORERS FOR TELEGRAPH POLES.

By John Gavey, M.S.T.E.

(Abstract of a Paper read before the British Society of Telegraph Engineers, November 25th, 1874.)*

In the present age, when labor is daily becoming more costly, and labor-saving appliances are gradually superseding mere physical strength in all mechanical operations, it may be well to inquire what improvements have been introduced with the object of reducing the expenditure of manual force in, and the cost of, the erection of telegraph poles. The old method of digging a post-hole by means of a spade and pickaxe is so well known as to need no description. Some years ago a pole 24 feet long by 5 inches diameter at the top was considered a fair length for a main line. Now, lengths of 28 and 30 feet, with a minimum diameter of 6 inches at the top, are as a rule adopted.

The depth at which it is customary to plant telegraph poles may roughly be considered to vary from 4 feet 6 inches for a pole 24 feet long, to 5 feet 6 inches for one 28 or 30 feet; 6 feet serving up to, say, 40 feet, and 7 feet for any height employed beyond.

Now, the number of pole-holes which an ordinary laborer, accustomed to the work, will dig in a working day of ten hours, will obviously depend on the depth which he has to reach, and the soil in which the poles have to be planted. We may assume, as before indicated, that the average depths will vary from 4 feet 6 inches to 5 feet 6 inches, and the soils may conveniently be divided into: 1st, clay; 2d, ordinary soil, requiring some use of the pickaxe; 3d, hard gravel; 4th, chalk; and 5th, rock.

It may be taken as the result of experience that the average number of holes which a workman will dig in ten hours is represented in the following Table:

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* Reprinted from London *Engineering*.

Soil.	No. of Holes per Day.	
	4 ft. 6 in. deep.	5 ft. 6 in. deep.
Clay	6	5
Digging soil	5	4
Hard gravel	4	3 to $3\frac{1}{2}$

Chalk and rock may for the present be left out of consideration. For these there appears no alternative but the pickaxe, bar, spade, and, occasionally, blasting.

It will, of course, be obvious that the most ready means of diminishing the labor involved by these operations will be the reduction of the size of the hole; for we actually require but a cylindrical space, varying from 10 to 14 inches in diameter, with an average cubical content of 3·5 feet and a weight of materials of 376 lbs. for a 4-feet 6-inch hole; the contents of one 5 feet 6 inches deep being taken at 4·3 cubic feet, weighing 460 lbs.

Perhaps the earliest attempt in this direction was made in Spain, where an instrument since known as a "Spanish spoon" was introduced. This was reported to have worked very successfully. It may be said to have consisted of a section, or arc, of a circular metal disc; the chord of the arc forming a cutting edge. The periphery of the disc was provided with a ledge about two inches high, to retain whatever might accumulate on its surface, and the whole was fixed at right angles to a long handle. To dig a hole with this machine, the soil was first loosened by means of a bar, and the machine being inserted, a circular or rotary motion was imparted to it, by means of its handle, whereby the loosened soil was accumulated on its surface and removed from the hole.

A similar instrument was tried in this country, but the results obtained were not so satisfactory as was expected.

The average speed with which a pole-hole, varying from 4 feet to 4 feet 6 inches, was dug, did not exceed that of the ordinary method; but, of course, an advantage was presented by the new system in the additional solidity of the pole when erected, and in the diminution of the quantity of soil which had to be filled and rammed in. It was observed that after a depth of about 3 feet 6 inches had been reached, the difficulty of loosening and collecting the soil appeared to increase, and the speed of working to decrease, as the square of the additional depth, so that the plan did not at that time promise much success with deeper holes for heavy timber.

The most marked improvement in the method of forming holes for telegraph poles appears to have been the introduction of earth borers, amongst which may be mentioned those invented by Spiller, by Marshall, and by Bohlken.

In most soils these instruments obviate the necessity of breaking up and loosening the materials with a bar, and moreover they collect the débris with much greater facility than is possible with a Spanish spoon.

Spiller's borers may be described as a huge modification of the old-fashioned ship's auger. It consists of a plate of sheet iron, bent into the form of a semi-cylinder, attached vertically to a long handle. At the lower extremity, and at right angles to it, are two quadrants of sheet steel, one slightly bent downwards, which forms the cutting plate, the other, which occupies the second half of the semi-cylinder, is bent upwards, and serves to retain the débris as it is cut up by the lower plate.

Marshall's borer is thus described in his specification:

"The auger blade is made of a flat plate or disc of metal, severed in a radial direction from the centre or boss, on which the blade is carried, to the circumference, the two ends of the blade thus formed being bent apart of a V form in edge view. The edge or point which is bent downwards or projects from the lower surface of the blade forms the cutting edge, the earth removed thereby on the rotation of the auger passing through the radial opening between the two ends on to the upper surface of the plate, whence it is removed from time to time by raising the auger. The auger or blade is fixed at right angles on its shank or stock, which is formed with a square end to receive the boss of the blade. The latter is secured by a tapering metal point screwed on to the extremity of the stock. The point is provided with a quick spiral groove or grooves to form a reamer for the purpose of drilling a hole in advance of the boss of the auger, and so facilitate the penetration of the latter. The stock of the auger is attached to two or more sections of tubes screwed together and provided with sockets for the cross handle used for rotating the auger."

Bohlken's borer is an instrument very similar to that introduced by Marshall. The principle appears to be exactly the same.

These borers should invariably be accompanied by a narrow long-handled shovel and a punner bar, so called. This bar consists of a long hollow rod, at one end of which is a chisel point for loosening the soil, breaking and removing stones, etc., and the other a peculiarly-shaped punner head for ramming and consolidating the soil around this when it is erected. The shovel is found to be of much service in removing stones and other obstructions which interfere with the passage of the auger. These augers are worked by two men who rotate them steadily, withdrawing them from time to time with their superincumbent load of soil.

Spiller's borer was found by the author to be very effective in sand, clay, and ordinary soil. It, however, was not so successful in gravel, as it would not bore through it. The whole of the material had to be disturbed and broken with a bar, the borer then simply acting as a spoon, and a somewhat clumsy one, to remove the débris. Moreover the radial opening between the plates appeared too small to admit of the passage of ordinary gravel and stones. It is, however, probable that the instrument might be so modified as to give better results with the last-mentioned soil. The machine itself is very strong, will bear much rough usage, and does not appear likely to break or get damaged by hard work.

Marshall's borer is very effective in clay, ordinary soil, and gravel. It does not simply bore into the ground like a common screw pile, for then it would be impossible to withdraw it. The action of the cutter takes slice after slice of the soil, raising each through the height of the groove, thereby severing it from the circumference of the hole, without otherwise disturbing its position. A small valve exists in the tapering point of the machine, which is movable by means of a lever or eccentric and connecting rod which passes down the hollow stem. The object of this is to admit of the introduction of air under the plate in such soils as would otherwise tend to form a vacuum on the withdrawal of the closely packed borer, thereby adding the weight of the atmosphere to that of the materials raised.

The cutting plates, which are interchangeable, vary from 10 inches to 12 inches in diameter. These sizes will, as a rule, serve for the majority of poles erected; but the hole can, if necessary, be easily enlarged with a properly-formed shovel, by cutting down the sides and raising the soil with a borer.

With this machine, a hole has been bored a depth of 5 feet 6 inches, in clay, by two men, in 20 minutes, and the pole erected and completed in half an hour; and holes in gravel have been opened up a like depth, in a time varying from 30 minutes to an hour with the same strength.

There is obviously a very considerable saving of labor in filling in and ramming the bored hole, as compared with that dug in the ordinary manner. It may be mentioned that in boring through gravel it is found necessary to drive the bar down the centre of the hole, well in advance of the borer, to admit of the entrance of the tapering point which forms the extremity, in order to get through the gravel at a fair speed. The ordinary rotating motion does the remainder of the work.

Bohlken's borers appear the same in principle as Marshall's, and would probably do like work. The author has not used them.

These borers have obviously one defect. They cannot be worked close to a wall or a hedge, positions where, in road telegraphy especially, it is frequently necessary to erect poles This difficulty has been overcome by fitting one of the borers with an ordinary rachet handle, lightening such of the parts as admit of it, and replacing the long tapering point by a shorter one. This modified instrument will bore in clay and ordinary soil, but in gravel it only acts as a spoon, the soil having to be broken up with a bar.

The advantages of these apparatuses may be summarized as follows:

1. *Speed.*—A number of pole-holes can be opened out to a given depth, with the same force of men, in less time than by ordinary methods.
2. Diminution of labor in filling in.
3. Greater solidity of the pole thus erected.
4. Less disturbance and mixing up of the soil, a point of some consequence in erecting lines of telegraph through private property.
5. The advantage of being able to work in wet soils without baling or pumping.
6. Saving of expense in sharpening and laying pickaxes.

Among the disadvantages may be mentioned:

1. Strain involved in raising the borers out of heavy soils with their load of débris.
2. The difficulty, and, with inexperienced men, danger, in rearing the pole into the hole, when the former is very heavy.
3. Liability of the screw borers to fracture, and additional first cost.

After the reading of the paper, Mr. Gavey explained the various apparatuses and the method of working them.

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